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PREPARATION FOR AN OBJECTIVE TEST IN MECHANICAL DRAWING - GRADE X A MIDYEAR TEST

Submitted by

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(A.A., Harvard, 1942)

In partial fulfillment of requirements for
the degree of Master of Education
1946

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CHAPTER I

PRESENTATION OF THE PROBLEM

Purpose and Scope

Purpose of the thesis.-- The purpose of this thesis is to prepare an objective test in elementary mechanical drawing for a local high school, namely, Boston Technical High School. It has been planned as a midyear test in grade X of this school where mechanical drawing is taught three -40 minute periods a week. The thesis is composed of two parts, namely; (1) the teaching objectives, and (2) the test. The writer believes that both the objectives and test can be useful in high schools where educational aims are of a general nature.

To insure a valid test from a curricular standpoint, the teaching objectives of the course are delimited and the test items matched with these objectives by a code. For example, see page 8 of Chapter II (O-6) and page 81 of Chapter III (O-6). The teaching objectives are grouped under five units of instruction, and each unit is delimited in Chapter II. "The delimitation of a unit is a statement of the lesser learning products which are components of the unit and which are to be made the direct object of instruction in a given class of a given grade level in a given situation within a

given time allotment"[1] These objectives of teaching have been checked for accuracy in several textbooks in mechanical drawing (see bibliography).

Scope of the thesis.-- The writer has purposely left out the topic of Lettering from this thesis, because he does not believe that it can be tested objectively; that is, without the judgment of the marker entering into the mark. The teaching objectives are grouped under the following headings: (1) Instruments and Materials, (2) Laying-out a Three-view Drawing, (3) Geometric Problems, (4) Orthographic Projection, and (5) Dimensioning. In the teaching objectives of Chapter II, these topics have been delimited, but the test, Chapter III, only samples these topics.

For this reason, the teaching objectives may serve as a source of material for other tests in elementary mechanical drawing. The test prepared in this thesis could be called Form A. There is sufficient material for the making of another test which could be called Form B.

The test in this thesis is entirely objective, and is composed of six parts as follows: (1) a true and false test, (2) a matching test in the geometry useful to mechanical drawing, (3) a completion test in geometric construction, (4) a multiple-choice test on computing the margins in an orthographic drawing, (5) a completion test in orthographic

1/ Roy Billett, Fundamentals of Secondary-School Teaching with Emphasis on the Unit Method, Houghton Mifflin Company, Boston, 1940, p. 505.

projection, and (6) a blueprint reading test. A more detailed description of the test is given in Chapter III, pages 74 to 77.

Definitions, Aims and Objectives of Mechanical Drawing.

Definitions of mechanical drawing.-- Herman A. Pohlman and Joseph W. Slyva[1/] of the Newton Public Schools put forth these thoughts:

> Mechanical drawing is the universal language of the industrial world. Plans or drawings made in one country can easily be understood in other countries. The symbols and the expressions of the language are the same through-out the world. The lines are the letters of the language. The single views and the symbols are the words. The projection of views form the sentences and the complete drawing of a single object form the chapter. A complete set of drawings from which an entire structure or machine can be built represents the book of the drawing language.

William W. Klenke and Charles J. Hayes[2/] offer the following definition.

> Mechanical Drawing is the language of industry. It depicts objects of three dimensions on the surface of a sheet of paper having but two dimensions. By means of lines, drawn by the aid of mechanical drawing instruments, various views of an object are represented, full size or to scale, so that the mechanic in the shop or on the job will be able to interpret them and thereby make the piece of machinery, build the house or construct the bridge.

Aim of mechanical drawing.-- The aim of a mechanical drawing course is to acquaint the pupil with the language of

1/ Herman A. Pohlman and Joseph W. Slyva of Newton Public Schools, The Story of Mechanical Drawing, a mimeograph pamphlet, 1941, p. 4.

2/ William W. Klenke, and Charles J. Hayes, Elementary Mechanical Drawing, International Textbook Company, Scranton, Pennsylvania, 1944, p. 1.

the industrial world. In learning this language, the pupil must understand its principles, develop skill in the execution of its symbols and acquire a reading knowledge of its blueprints.

Objectives of mechanical drawing.-- Although some general objectives may be found in a study of the definitions of mechanical drawing, no general objectives will be as worth while as the delimitations of the units of the course. The validity of a test should be judged by the degree to which the test items meet the objectives of the course. As previously explained, the test items match the teaching objectives. However, it should be determined whether or not these teaching objectives are of themselves valid. We must answer the question, "Do the objectives of mechanical drawing fit into the general objectives of the school in which they are taught?" Boston Technical High School has a dual purpose. "It prepares students for technical institutes and colleges. It provides, too, the necessary knowledge and training which in time will enable graduates to fill the intermediate jobs in the industrial world, executive positions which demand a high degree of technical insight and judgment."[1/] The writer feels that the teaching objectives as set forth in Chapter II of this thesis, fulfill in good measure the fundamentals of learning the language of industry which is mechanical drawing.

1/ Bulletin of the Boston Technical High School, City of Boston Printing Department, June 1945, p. 10.

CHAPTER II

OBJECTIVES OF THE COURSE

Instruments and Materials

Essential features of a good drawing board for the student of drafting.-- The draftsman must have a true flat surface upon which to firmly hold the drawing paper in place. A board approximately 16" by 21" is a convenient size for the student. It will accommodate a 9" by 12" and 12" by 18" or an 8½" by 11" and 11" by 17" paper. (O-1)[1/]

Drawing boards made of soft white pine will hold their shape well. Properly constructed boards are provided with two end cleats, as shown in Figure 1. The working edge of the drawing board should be perfectly straight and at right angles with the top flat surface. (O-2)

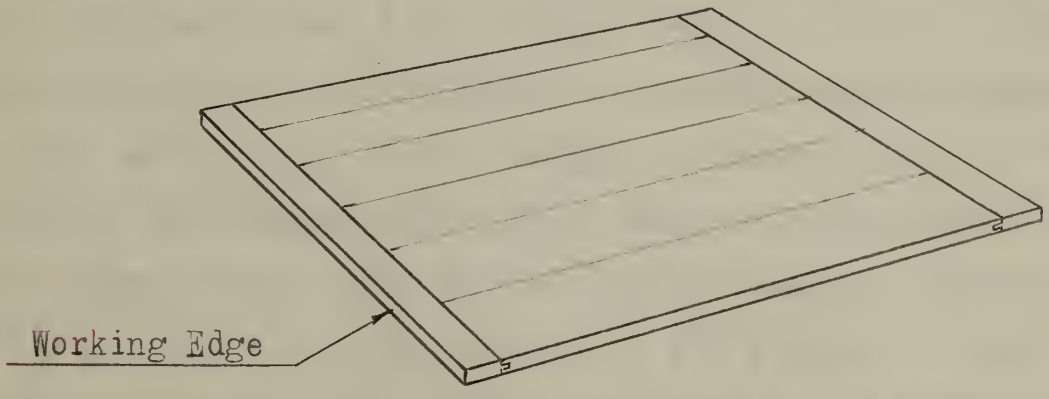


Figure 1 - The drawing board.

1/ (O-1) means teaching objective number one.

The T-square as a most important tool of the draftsman.--T-squares are made of two main parts, the head and the blade, (Figure 2). The blade is edged with celluloid, enabling the user to see under the edge. Five small screws fasten the blade to the head. The angle that the blade makes with the head does not necessarily have to be exactly 90 degrees, but whatever this angle is, it should remain fixed. To insure a fixed angle between the head and blade, the T-square must be handled very carefully. (0-3)

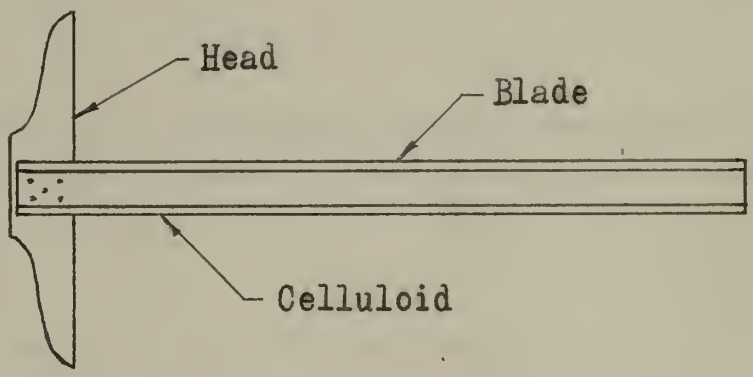


Figure 2 - The T-square.

It is the head of the T-square that is placed against the left-hand edge of the drawing board, as shown in Figure 3. In this position the T-square is used for drawing horizontal lines. As the head of the T-square is moved along the working edge of the drawing board and a series of horizontal lines are drawn, these lines will all be parallel to each other. This condition will result only if the T-square is held with its head tight against the working edge of the drawing board and if the working edge is perfectly straight. When drawing horizontal lines, the pencil should be placed only against the top edge of the T-square blade. In a fairly recent

textbook of mechanical drawing, William H. Johnson and Louis V. Newkirk[1/] make this statement. "All horizontal lines are drawn along the upper edge of the blade and from left to right by a right-handed person." (0-4)

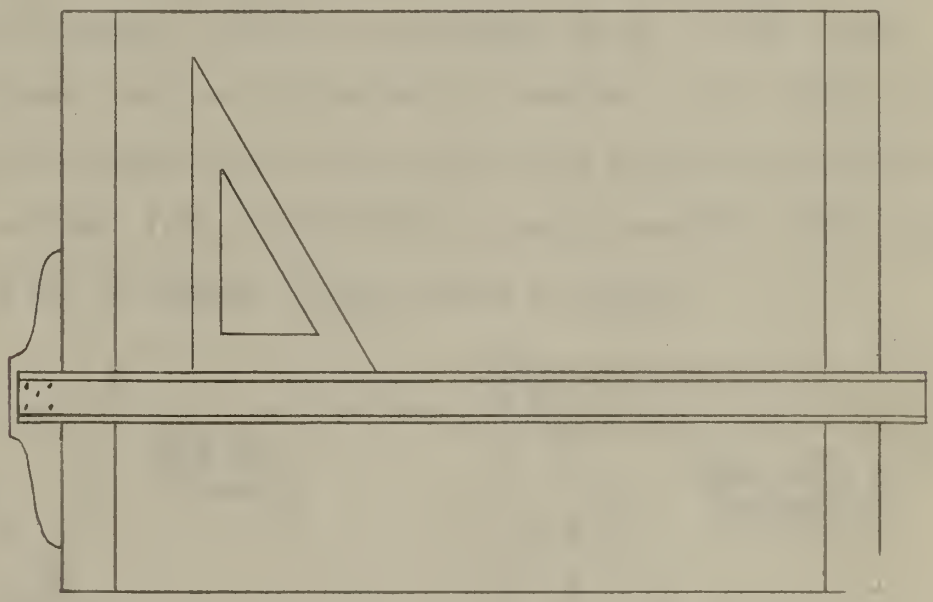


Figure 3 - Position of T-square and triangle for drawing vertical lines.

For drawing vertical lines the T-square and triangle are used in combination as shown in Figure 3. The triangle is placed upon the T-square with the vertical edge of the triangle at the left. When drawing vertical lines, the draftsman holds both the T-square and triangle with his left hand. Holding the pencil with the right hand and with the lead of the pencil against the vertical edge of the triangle, draw

1/ William H. Johnson and Louis V. Newkirk Modern Drafting, The Macmillan Company, New York, 1944, p. 4.

from the bottom upward. (0-5)

Properties of the triangles.-- Two triangles are employed by the draftsman, one a 45° and the other a 30°-60°. They are transparent, being made of celluloid, and are manufactured in a variety of sizes. Johnson and Newkirk[1/] in their text on Modern Drafting recommend an 8- or 10- inch 30°-60° triangle and an 8-inch 45° triangle. It is essential that these instruments are true, that the angles are exactly 30°, 60°, and 90° for the 30°-60° triangle and 45°, 45°, and 90° for the 45° triangle. (See Figure 4.)(0-6)

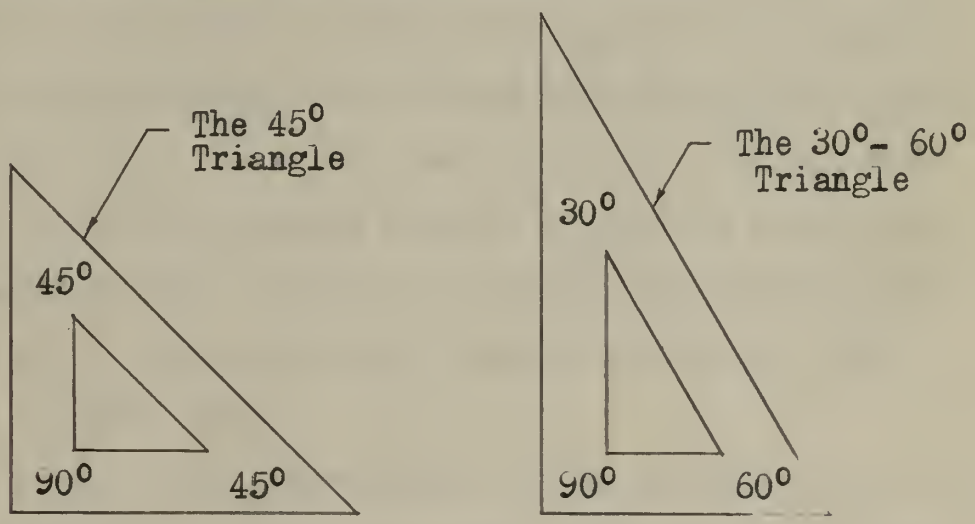


Figure 4 - The draftsman's triangles.

If it is desirable to draw a series of oblique lines, all parallel to each other, the T-square and triangle may be employed in combination, as shown in Figure 5. (0-7)

1/ Ibid.

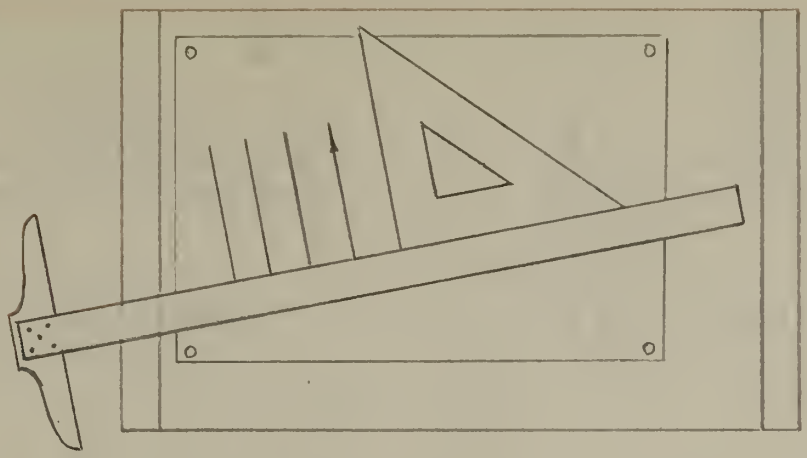


Figure 5 - Use of T-square and triangle for drawing parallel lines.

Figure 6 (see page 10) shows the application of the T-square and triangle to obtain the angles most commonly used by the draftsman. It is clear from the figure that horizontal lines should be drawn from left to right and vertical lines from bottom upward. It will be helpful to the student to bear in mind the geometric principle that the sum of the angles of any triangle equals two right angles, or 180°. (0-8)

To draw a line perpendicular to an oblique line, the T-square and 45° triangle are used. Two methods are shown in Figure 7, (see page 7) method A and method B. For method A the hypotenuse of the 45° triangle is first lined-up with the given oblique line. The T-square is placed in position at the base of the triangle. The triangle is then turned over as shown by the dotted lines in Figure 7-method A and the required perpendicular is drawn.

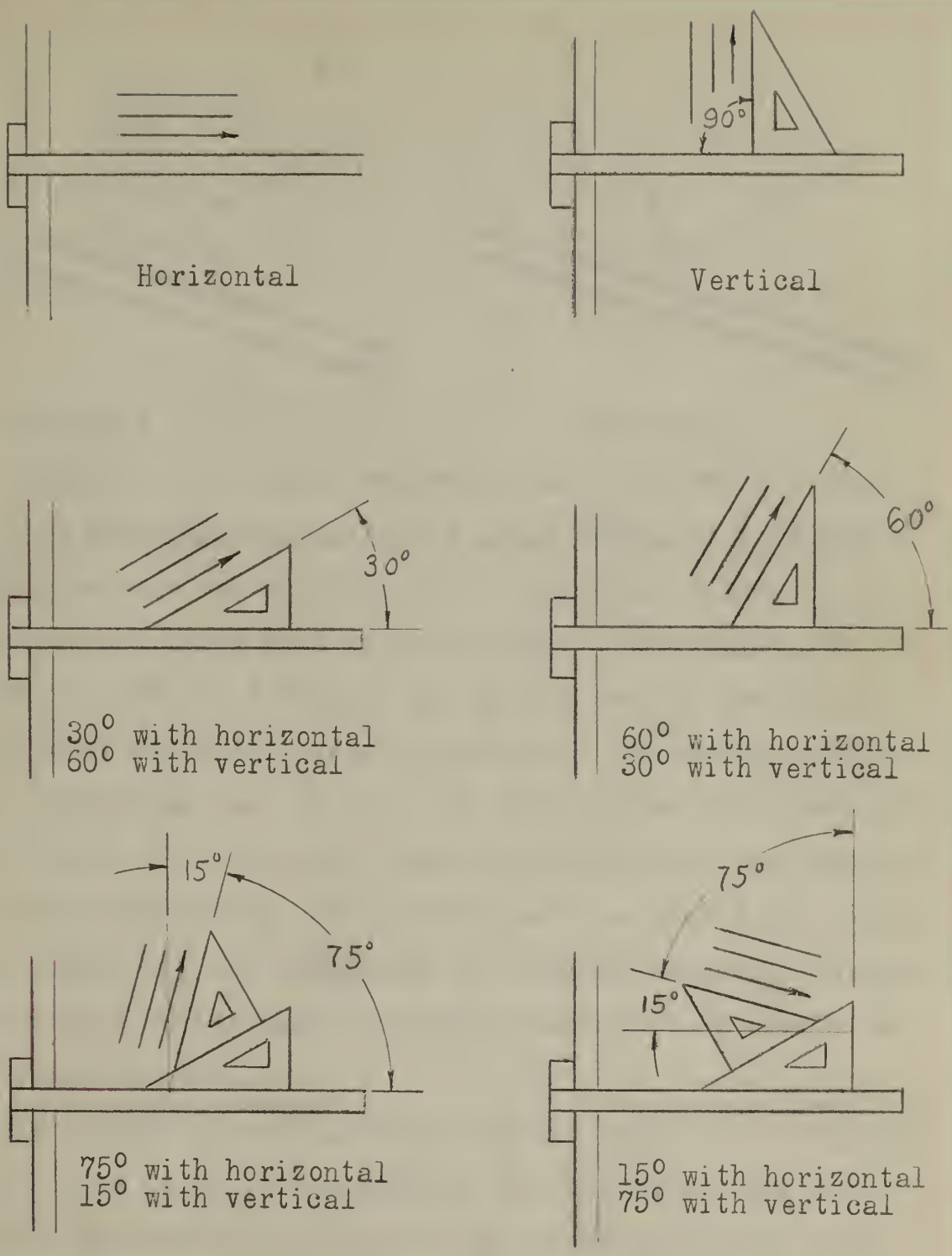
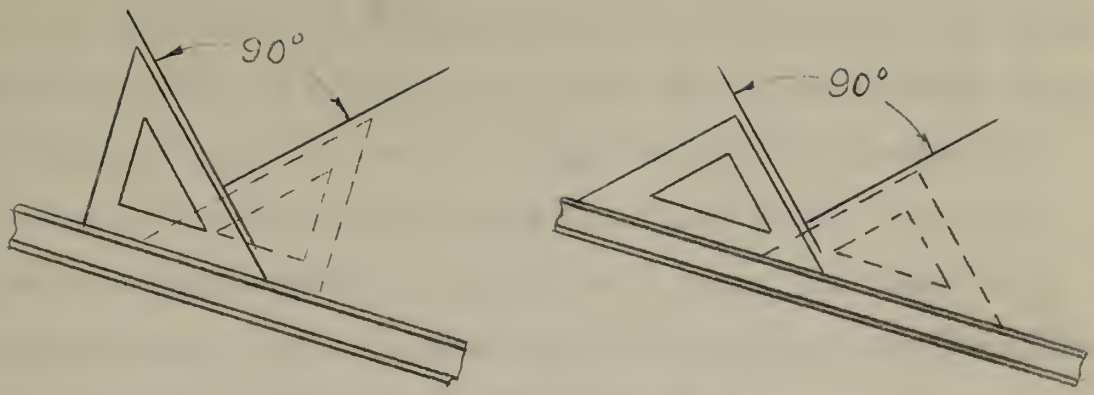


Figure 6 - The use of T-square and triangles.[a/]

a/ Adapted from William W. Klenke and Charles J. Hayes Elementary Mechanical Drawing, International Textbook Co., Scranton, Penn., 1940, p. 22.



Method A Method B

Figure 7 - To draw a perpendicular to an oblique line.

The draftsman's pencils and their degree of hardness.--Drawing pencils are manufactured in different grades of hardness. They range from 9H, the hardest, through 8H, 7H, 6H, 5H, 4H, 3H, 2H, H, F, HB, B, 2B, 3B, 4B, and 5B the softest. For general mechanical drawing purposes, the hardest pencil that a draftsman need use is a 4H. The 4H pencil is used for layout work, blocking out a drawing, guide lines for lettering, and dimensioning. An H or 2H pencil is good for lining-in a drawing and for lettering. In freehand technical sketching, where a softer paper is usually used, the HB pencil is preferable. (0-10)

To sharpen a pencil, insert the end opposite the lettering into the mechanical sharpener. It is wise to save the lettered end so that the pencil may be identified for grade of hardness. After a conical point is obtained in the mechanical sharpener, the pencil should be placed upon an emery or

sandpaper stick as shown in Figure 8. Some draftsmen prefer a file. The pencil is drawn back and forth across the emery stick to obtain a sharp lead point. While being drawn across the emery stick, the pencil should be rotated between the thumb and forefinger to insure a conical point. Some instructors prefer a chisel point or a point the shape of a darning needle, but for grade ten the conical point is best. Many draftsmen prefer this type of point.

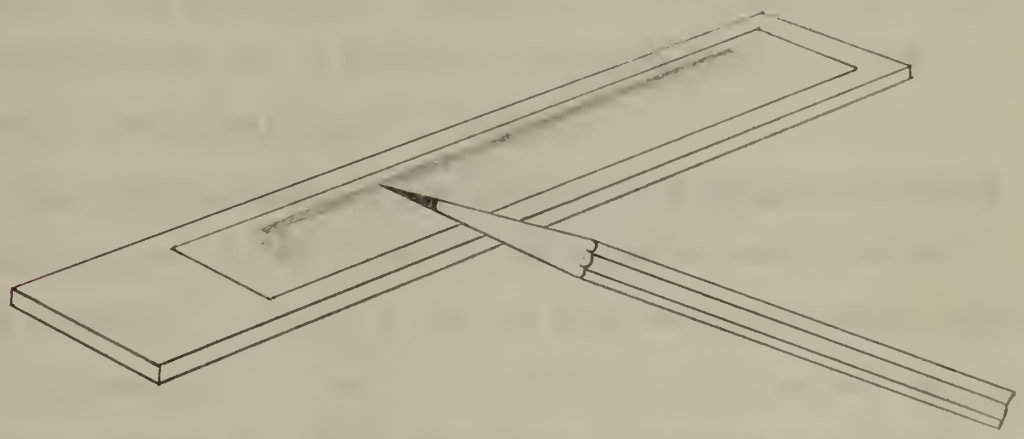


Figure 8 - Sharpening a pencil on an emery stick.

In the drafting rooms of the public schools, the mechanical pencil sharpener has a distinct advantage over the use of a knife. There is no danger of cutting a finger with the mechanical sharpener. (O-11)

The architect's triangular scale as a series of separate scales.-- By means of the architect's scale the drawing of an object may be made in full size, larger than full size, or smaller than full size. One edge of the architect's scale has the common rule of 12 inches to the

foot divided into 1/16" graduations. This scale is marked 16 at the left hand end and is used in making full size drawings. (0-12) Johnson and Newkirk[1/] have this to contribute: "The other scales range from 3/32"=1'-0" to 3"=1'-0". These are paired two to an edge and marked to show scale divisions of 3/32" and 3/16"; 1/8" and 1/4"; 1/2" and 1"; 3/8" and 3/4"; and 1½" and 3". Each unit on any of these scales represents a foot of actual measurement reduced to a particular length.----- The foot units lie to one side of the 0 mark and the inch units to the other." (See Figure 10) (0-13)

The major units of the architect's scale as inches or as feet.-- The architect's triangular scale serves a dual purpose, in that it may be used when the major units or divisions are to be read as feet (as explained in, (0-13) or when the major units or divisions are to be read as inches. In the latter case, the inch units would lie to one side of the 0 mark and the fractions or parts of an inch (preferably 16 parts or units) would lie to the other. This is brought out in Figure 9 in the scale of 3/4"=1". The divisions to the right of the 0 mark should now be divided into 16 parts. This is difficult to do because the scale was originally laid out in twelve parts to represent the twelve inches in a foot. (0-14)

1/ Op. cit. p. 5.

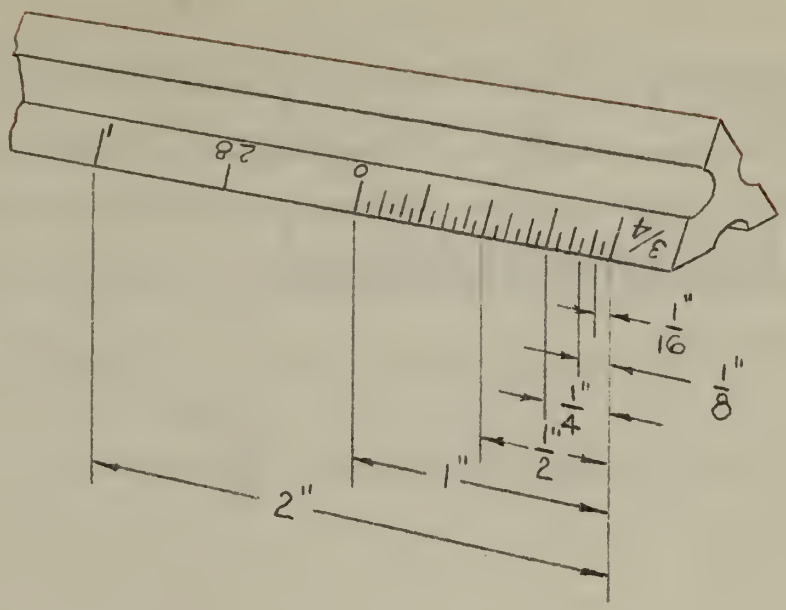


Figure 9 - The architect's scale used as $\frac{3}{4}$"=1"

For a comparison of the two different ways the same scale may be used, see Figure 10. When the scale of $1\frac{1}{2}$"=1' is used, 1 foot and $4\frac{1}{2}$ inches (for instance) will be read as shown on the figure. The 1 foot is read to the left of the 0 and the $4\frac{1}{2}$ inches is read to the right of the 0. When the scale of $1\frac{1}{2}$"=1" is used, then this same measurement (1 foot and $4\frac{1}{2}$ inches) becomes 1 3/8", as shown on the figure. Now 1" would be read to the left of the 0 and 3/8" would be read to the right of the 0. In the first case (where $1\frac{1}{2}$"=1'), the graduations marked 3, 6, and 9 refer to inches, the foot being divided into twelve 1" parts. Each of these inch parts are divided into four parts, the smallest division or unit being $\frac{1}{4}$". When the $1\frac{1}{2}$" scale is used in this manner, it means that $1\frac{1}{2}$" on the drawing is

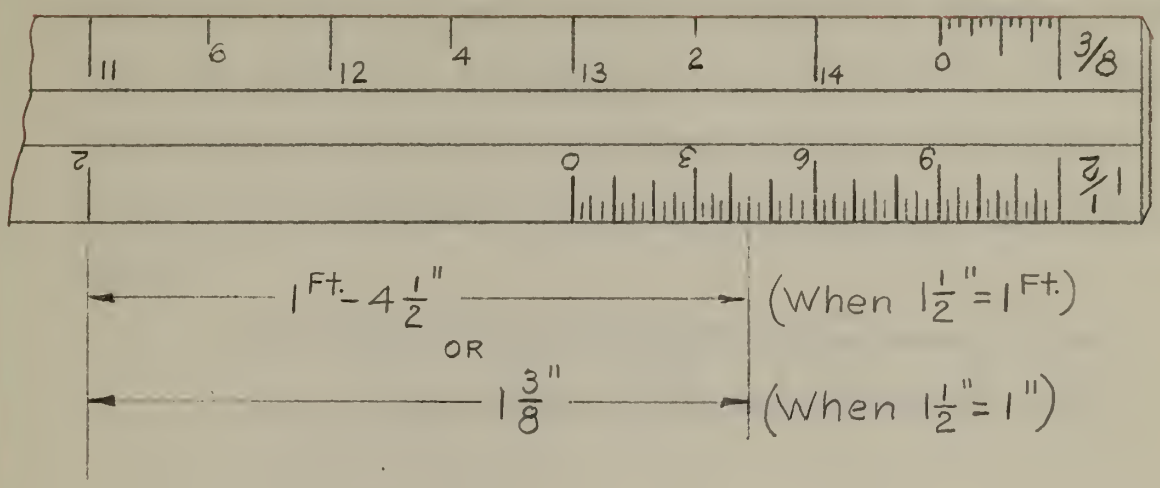


Figure 10 - Comparison of two scales.

equal to 1 foot on the object. It means that the drawing is 1/8 the size of the object, for 1½ can be divided into 12, eight times.

When the 1½" scale graduations are divided into fractions of an inch so that the whole distance from 0 to the end of the fine graduations equals one inch, then reference is being made to the 1½"=1" scale. From 0 to 3 would equal ¼", from 0 to 6 would equal ½", from 0 to 9 would equal ¾", and 0 to the end of the graduations would equal 1".

If 1/8" is desired, the distance from 0 to 3 on the 1½" scale would be divided in half, as shown in Figure 11. To obtain 1/16", it would be necessary to divide the 1/8" distance in half. One sixteenth of an inch on the scale of

1½"=1" would be a distance the equivalent of three of the very smallest divisions. This scale, 1½"=1" would be used where the object is small and a "blow-up" (a drawing larger than the object) is necessary to make it legible. The scale 1½"=1" means that 1½" on the drawing equals 1" on the object, or the drawing is 1½ times the size of the object. (O-15)

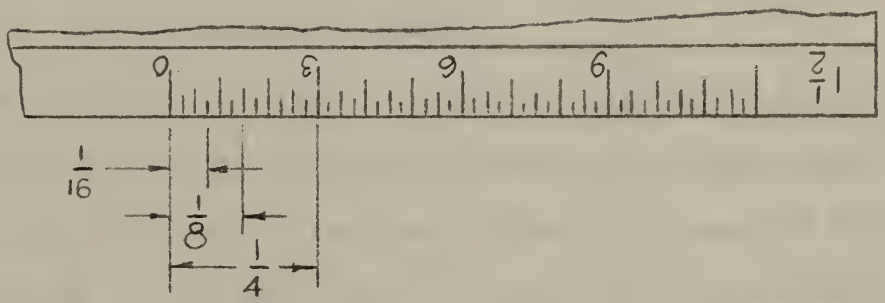


Figure 11 - Obtaining 1/16" on scale of 1½"=1".

The term "Drawing Instruments" as applying to the set of draftsman's instruments.-- The word instruments in the general sense refers to all the draftsman's tools, such as the T-square, triangles, architect's scale, compasses dividers and the bow instruments. The term, drawing instruments, refers in particular to a set of mechanical drawing instruments which are purchased in a case. Usually there are nine instruments in the case; the compasses, pen attachment or pen leg, lengthening or extension bar, dividers, bow pencil, bow pen, bow dividers and two ruling pens. In many public schools, drawing sets of eight instruments are used, one of the ruling pens being removed and to be used as a spare. (O-16)

It is absolutely essential for the student to take the

utmost care of all his instruments, but especially his set of instruments, for they are the easiest to misplace and to get out of adjustment. No instrument should be used by the student of drafting until the instructor has explained the use of it. All instruments should be checked by the student at the beginning of the drawing period and at the end. If any thing is found missing or broken, it should be reported at once to the instructor. (O-17)

The dividers are used to divide a distance equally and to transfer distances. When the spaces are less than 1", the bow dividers should be used. These instruments should be grasped by the handle (at the top of the instrument) between the thumb and forefinger of the right hand and adjustments made with the left hand. (O-18)

The compasses are used for making circles and arcs. It should be rotated between the thumb and first finger and should be used for radii 1" or greater. If radii less than 1" is desired, the bow compass should be used. Johnson and Newkirk offer an important concept: "If a circle is to be made larger than 3" in radius, the legs of the compass should be bent so that they are perpendicular to the paper".[1/] If a radius greater than 6" is desired, the lengthening bar should be inserted between the arm of the compasses and the pencil leg. (O-19)

1/ Op. cit. p. 8

The lead in the compass should be sharpened to a chisel point with the bevel on the outside as shown in Figure 12. (O-20)

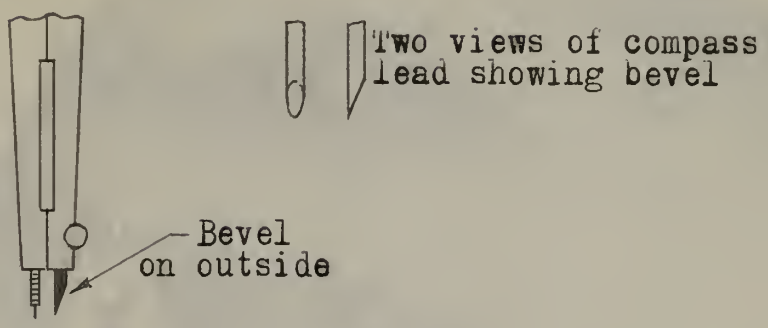


Figure 12 - Sharpening of compass lead.

Another type of compasses coming into popular usage in schools and drafting rooms is shown in Figure 13. There are large and small bow pencil compasses of this type called "Vemco" and manufactured by V. & E. Manufacturing Co., Pasadena, California. The large compasses measure 6½" in length and will describe circles up to 10 inches in diameter. They are rigid, light and will also describe circles only 1/8" in diameter. The center screw of this instrument articulates with the legs by cylindrical nuts. It is this center screw that makes these compasses so rigid. Very heavy pressure may be applied to get sufficient heavy grade of pencil line. Instruments of this type are produced by other manufacturers beside the V. and E. Manufacturing Co. A company named T. Alteneder, Philadelphia, manufactures a very good set of bow pencil compasses. Like the Vemco bow pencil compasses, the T. Alteneder has pen attachment and ruling pen. (O-21)

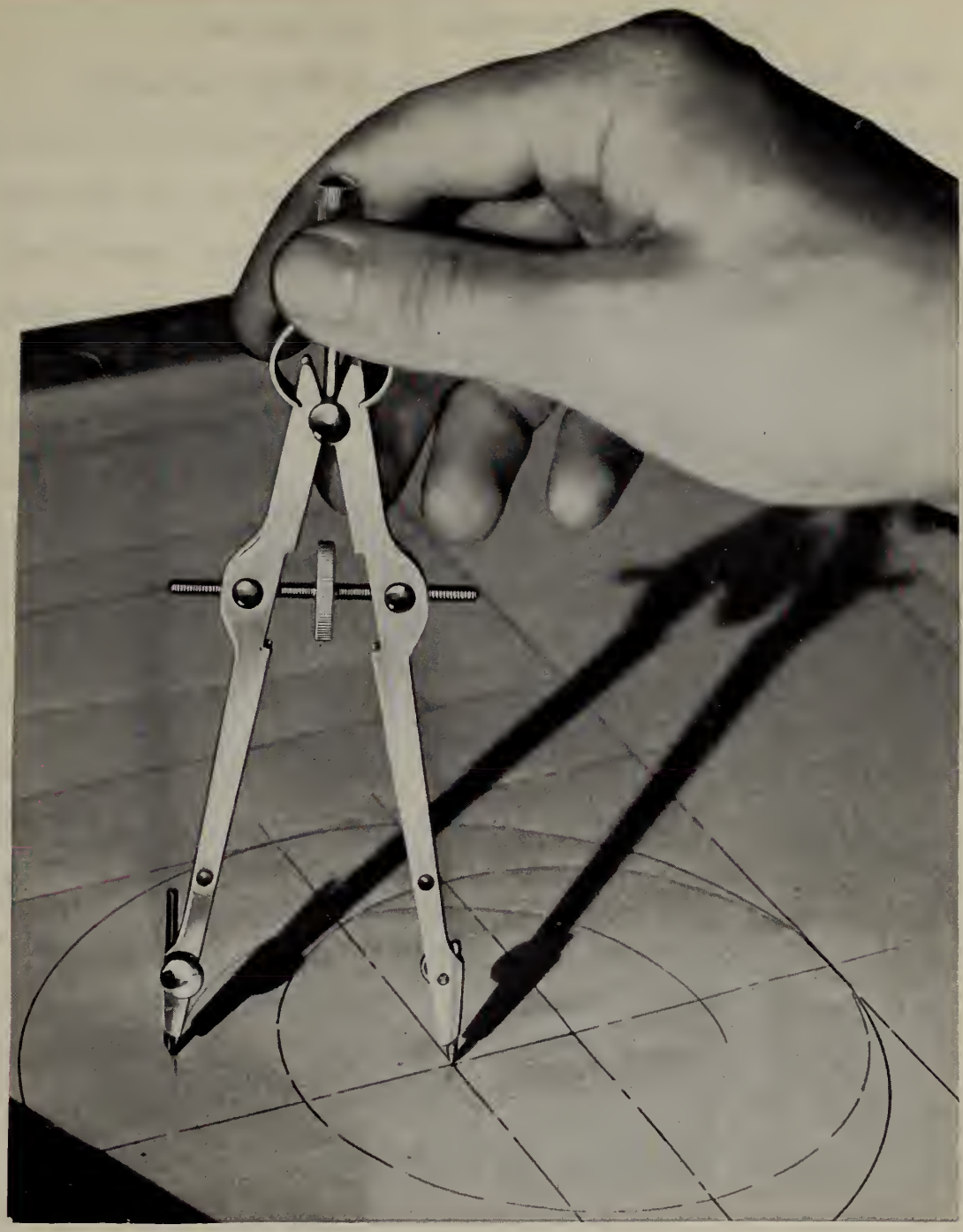


Figure 13 - "Vemco" large bow pencil compasses.[1/]

1/ Adapted from Vemco Drawing Instruments, a catalogue in pamphlet form distributed by The Morilla Company, Inc., 34-36 Cooper Square, New York 3, N. Y.

Laying Out a Three-View Drawing

Fastening paper to the drawing board.-- Thumb tacks, scotch tape and staples are used to fasten drawing paper securely on the drawing board. Scotch tape is replacing thumb tacks because the T-square and triangles will not slide over the thumb tacks easily. When drawing lines on the lower part of the paper, the thumb tacks prevent the T-square from lying flat upon the paper. Holes are made in the drawing paper and drawing board when thumb tacks are used. A good drafting tape may be used over again several times and it is reasonable in price. (O-22)

In fastening the drawing paper to the board, place the paper on the board nearer the top and left edges than the bottom and right. Just how close to the top and left edges the paper may be placed, will depend upon the size of the paper in relation to the board. For example, a paper cut 11" by 14" to be fastened to a board 16" by 21" might well be placed as shown in Figure 14. The top and left margins are approximately 1½". (O-23)

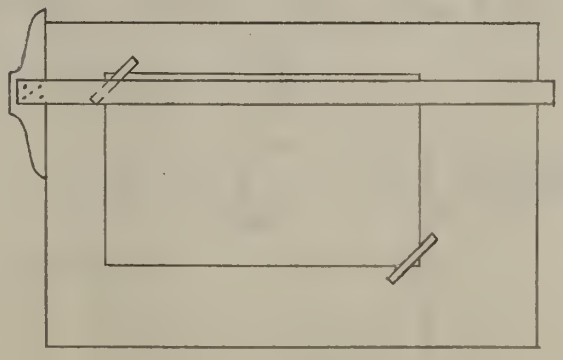


Figure 14 - Lining-up and placing of paper on drawing board.

Place a piece of scotch tape across the upper left hand corner of the drawing paper, adjusting the paper so that the top edge lines up with the top edge of the T-square. (Figure 14) Hold the head of the T-square against the left edge of the drawing board. With the T-square still in this position, place a piece of scotch tape across the lower right hand corner of the paper. Remove T-square and place scotch tape across the two remaining corners of the paper. (O-24)

Laying out border lines and title block.-- Some schools are fortunate enough to hand out to the student drawing papers with printed border lines and title block, which saves much time and labor for the student, and which conforms to drafting room practice. (O-25) If the student must lay out his own border lines and title block, he should first draw a horizontal line, very lightly, across the top of the paper about $\frac{3}{4}$" from the top edge, using the T-square. See Figure 15. All lines in a layout should, at first, be drawn lightly. Secondly, a vertical line about $\frac{3}{4}$" from the left edge of the paper should be drawn using the T-square and triangle. (O-26)

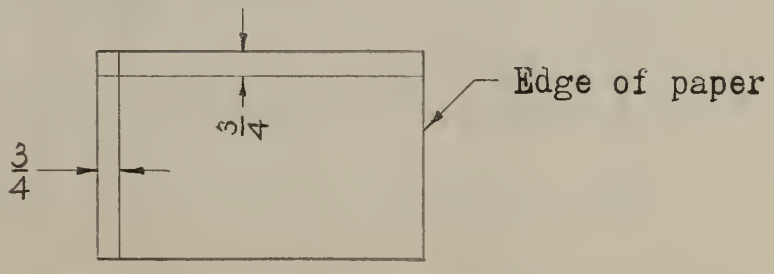


Figure 15 - Beginning of a Standard Layout.

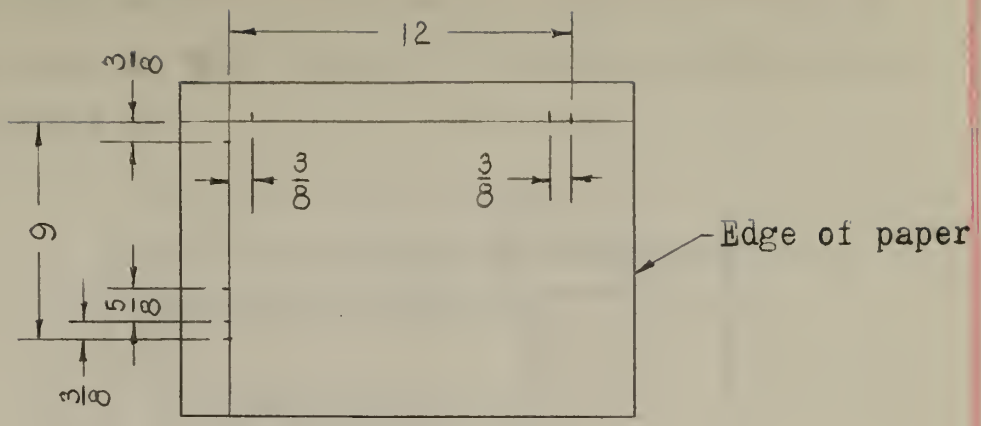


Figure 16 - Measurements for a 9" by 12" Standard Layout.

Figure 16 shows that all measurements for the layout can be made upon two lines, one horizontal and one vertical. Upon the horizontal line the overall length of 12" is laid out and the 3/8" margins as shown. Upon the vertical line the overall width of 9" is laid out plus the 3/8" margins and 5/8" title space.

With the T-square draw the horizontal lines as shown in Figure 17.

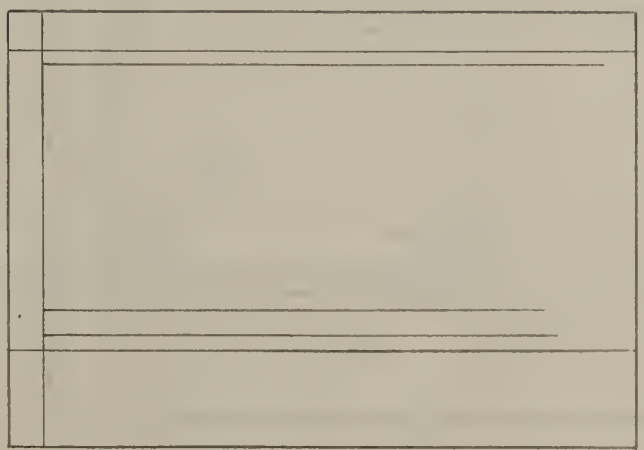


Figure 17 - Drawing the horizontal lines of the layout.

With the T-square and triangle, draw the remaining vertical lines and then line-in the inside border lines as shown in Figure 18.

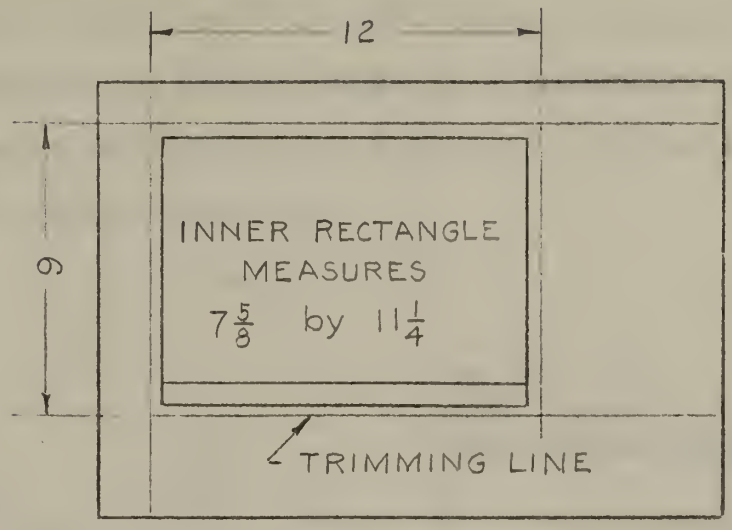


Figure 18 - Drawing the vertical lines and lining-in the inside border lines.

The completed 9" by 12" layout with the 5/8" title space is shown in Figure 19. The lining-in of border lines may be left until the drawing has been completed. (O-27)

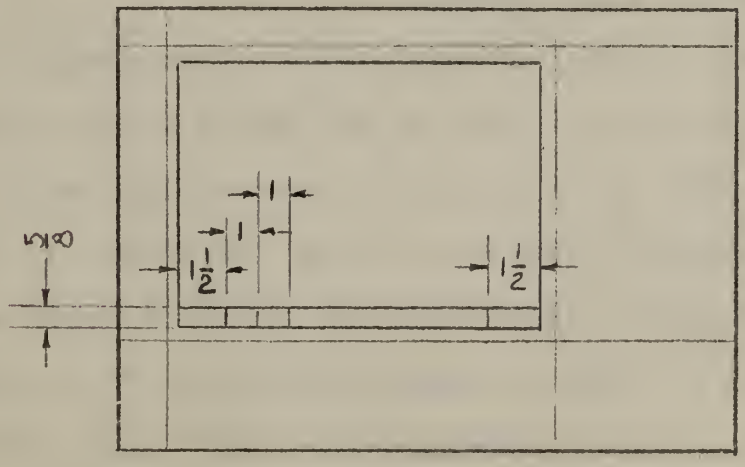


Figure 19 - The completed 9" by 12" Standard Layout.

The placing of a three-view drawing on a 9" by 12" standard layout.-- The working area of the 9" by 12" layout is 7-5/8" by 11-$\frac{1}{4}$". In an 8$\frac{1}{2}$" by 11" standard layout the working area would be 7" by 10". Three orthographic views of the perspective sketch shown in Figure 20 are to be placed (centered) within the 7-5/8" by 11-$\frac{1}{4}$" area of a 9" by 12" sheet, Figure 21.

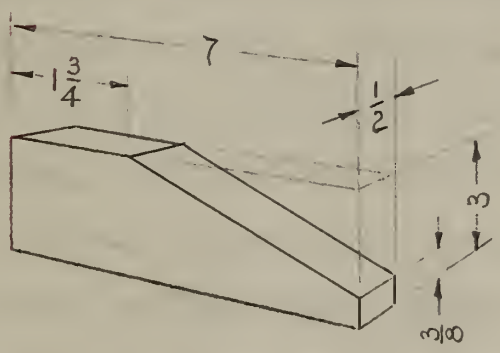


Figure 20 - Perspective

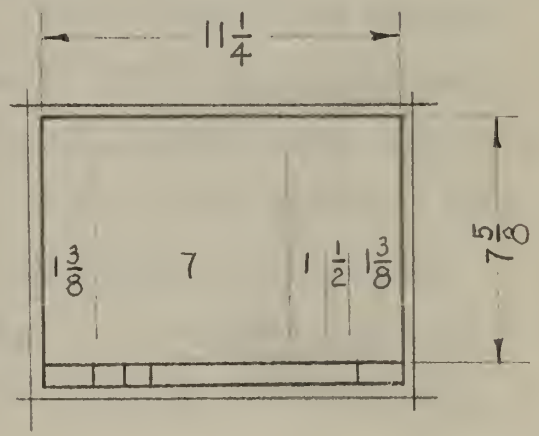


Figure 21 - Beginning the layout of a three-view drawing.

The student must first visualize shape, size and arrangement of the views. To do this, a study of orthographic projection (pages 45-56) should be made. The length and width of the object and the distance between views should be added together and this total subtracted from 11$\frac{1}{4}$". Thus if 1" is allowed between views, 7" (length of front view) plus 1" (distance between views), plus $\frac{1}{2}$" (width of side view) equals 8$\frac{1}{2}$". Thus 8$\frac{1}{2}$" subtracted from 11$\frac{1}{4}$" equals 2$\frac{3}{4}$". This is the total margin (left and right)

and therefore must be divided by two. The exact left margin and right margin will be 1-3/8". Now the views are said to be located horizontally. Light, fine vertical lines may be drawn ending part of each view, Figure 21. (0-28

Again allowing 1" between views; 3" (height of front view) plus 1" (distance between views) plus ½" (height of top view) equals 4½". Subtract 4½" from 7-5/8", this equals 3-1/8" which is the total of top and bottom margins. Dividing 3-1/8" by 2, we get 1-9/16" for the exact top margin and bottom margin, Figure 22. Light horizontal lines may now be drawn completely enclosing all three views. The three views, top, front, and right side, are now blocked-out. This should be the procedure for the three-view orthographic drawing of any object except when it is not desirable to center the views on the paper. The beveled cut can now be

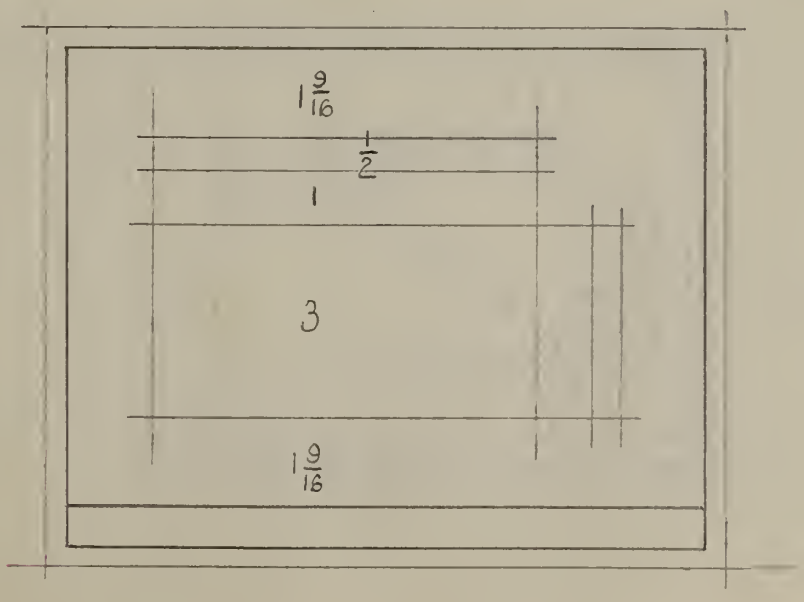


Figure 22 - Blocking out a three-view drawing.

made in the front view and projected to the top and right side. Erasures should be made and the drawing lined-in as shown in Figure 23.

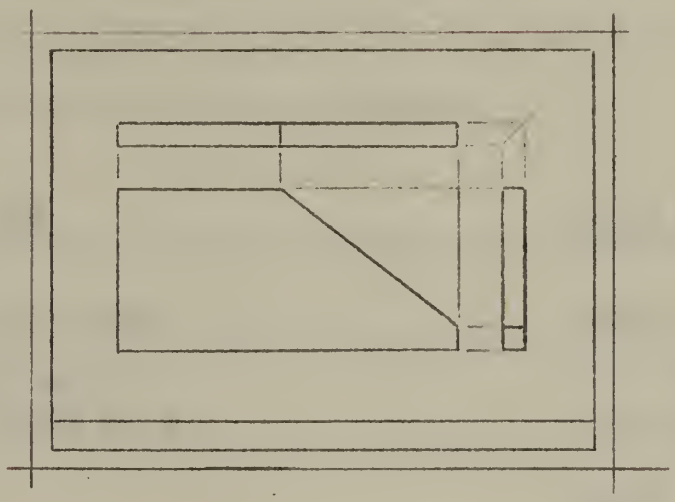


Figure 23 - Lining-in views.

When dimensions are added, the drawing will be finished and appear as shown in Figure 24. (0-29)

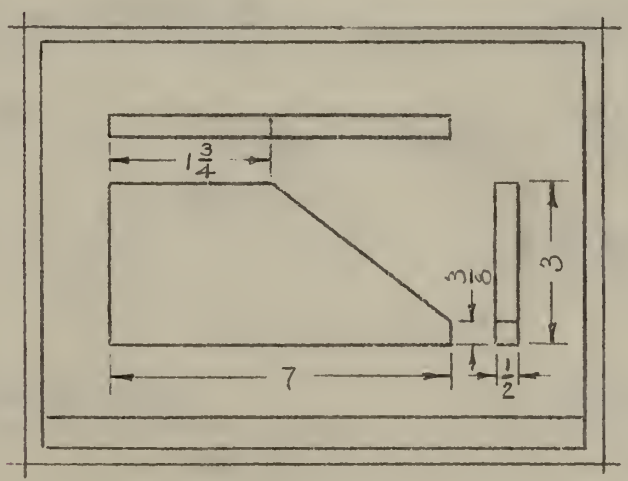


Figure 24 - A complete three-view drawing.

The alphabet of lines.-- Mechanical drawings will be more apt to have a sharp and attractive appearance if the student is skillful with his lines. Good drawings show a marked contrast between outlines and parts of less importance, such as extension lines. For an example of the various grades of line, see Figure 25.

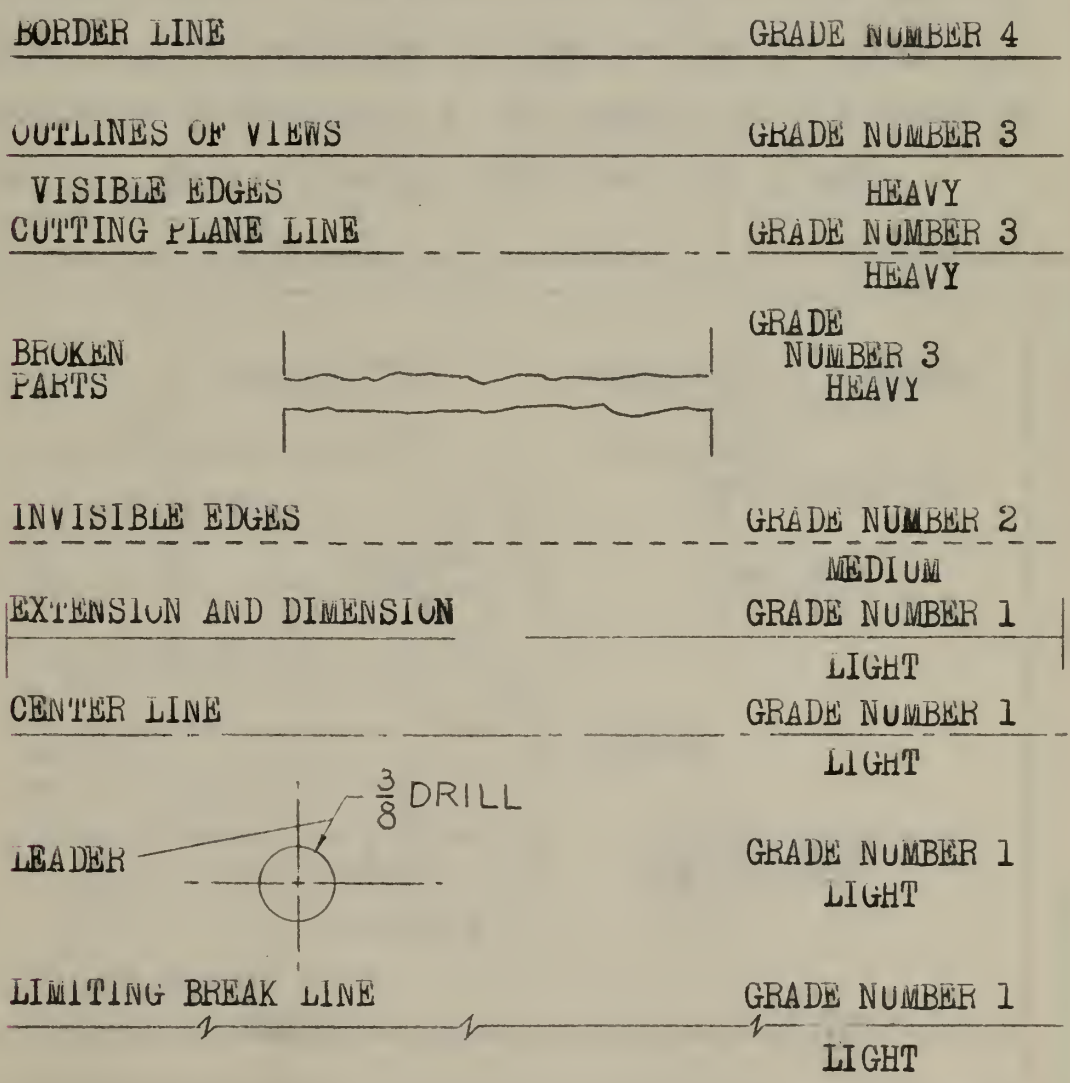


Figure 25 - The alphabet of lines.

The outline of views and all visible edges should be grade number 3, (heavy). The invisible edges should be made grade number 2, (medium). The dimension and extension lines should be made grade number 1, (light). Center lines, leaders and limiting break lines, are also light, grade number 1. The cutting plane line and broken parts (metal) are grade number 3. The border line may be made slightly heavier than the outlines of views and may be called for convenience, grade number 4. For example of the grades of lines in a working drawing, see Figure 26. (0-30)

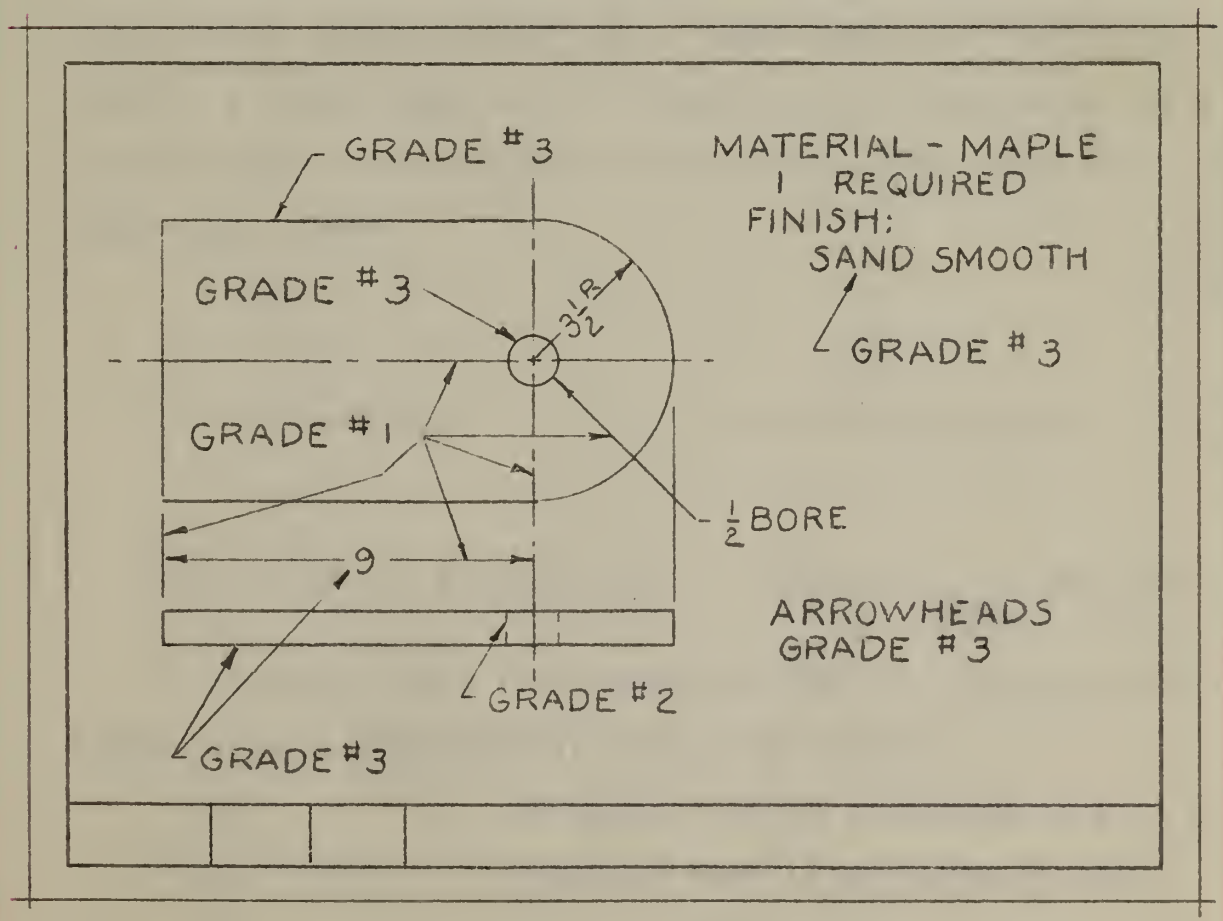
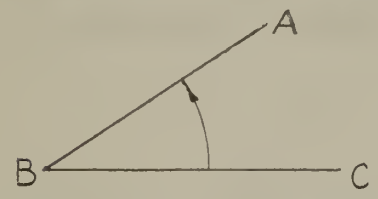


Figure 26 - Examples of grades of lines applied to a working drawing.

Geometric Construction

Types of angles and their definitions.-- The term "angle" may be thought of as being the opening between two lines meeting at a point



In Figure 27, AB and BC are the sides of the angle. The point B where the two sides meet is called the vertex.

Figure 27 - An angle. The size of an angle is dependent upon the amount of opening between its two sides. (O-31)

The size of an angle is expressed in terms of degrees of a circle. There are 90° in a right angle and 360° in a circle. A right angle may be thought of as one-quarter of a complete turn or one-quarter of a circle. See $\angle COB$ in Figure 28. (O-32

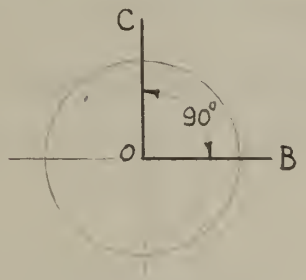


Figure 28 - A right angle.

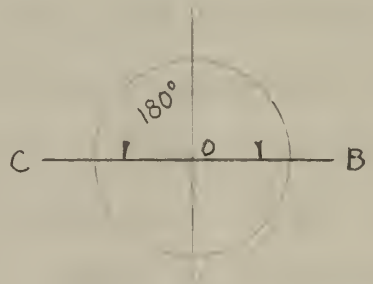


Figure 29 - A straight angle.

A straight angle is an angle of 180° or one-half of a complete turn. See $\angle COB$ in Figure 29. (O-33)

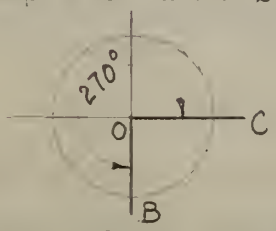


Figure 30 - A reflex angle.

An angle that is three-quarters of a complete turn is an angle of 270°, for example; three-quarters of $360=270^{\circ}$. See $\angle COB$ in Figure 30.

The type of angle shown in Figure 30 is greater than a straight angle and is called a reflex angle. (O-34)

The symbol for the word angle is "∠". In reading an angle, the vertex is always the middle letter. In Figure 31, for example, the angle may be read ∠COB or ∠BOC.

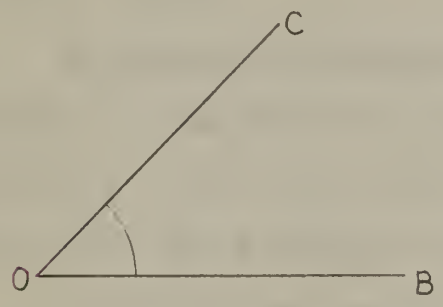


Figure 31 - An acute angle.

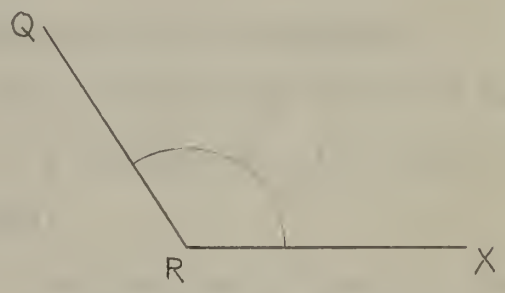


Figure 32 - An obtuse angle.

An acute angle is less than a right angle. See ∠COB, Figure 31. An obtuse angle is greater than a right angle, but less than a straight angle. See ∠QRX, Figure 32. (O-35)

Properties of a circle.-- In Figure 33, point "O" is the center of a circle and it is equidistant from any point on the circumference. (O-36) The radius of a circle is the distance from its center "O", to a point on its circumference as OA, OC, or OB. See Figure 33. All radii of the same or equal circles are equal. (O-37)

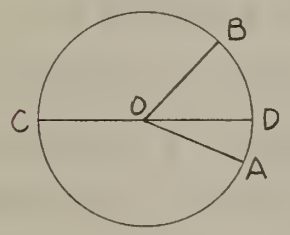


Figure 33 - A circle and its component parts.

The diameter is a line passing through the center of the circle and touching the circumference in two points as line COD in Figure 33.

A diameter of a circle is twice the radius.

A diameter of a circle bisects the circle. To bisect means to divide into two equal parts.

The vertical and horizontal diameters of a circle bisect each other and divide the circle into four right angles. (O-38)

A regular polygon as a special type of polygon.-- A polygon is an enclosed plane figure bounded by three or more straight lines. The perimeter of a polygon is its outline or the lines which enclose it. (O-39)

An equilateral polygon is a polygon which has all its sides equal. An equiangular polygon is a polygon which has all its angles equal. A polygon that is both equilateral and equiangular is a regular polygon. The pentagon, hexagon, and octogon are regular polygons only when they are both equiangular and equilateral. (Figure 34 shows a regular hexagon) (O-40)

A triangle is a three-sided polygon. An equilateral triangle is a triangle having all three sides equal. The draftsman's triangles are the 45° and the 30°-60°. (See page 4) In the 30°-60° triangle the hypotenuse is twice the short leg. (O-41)

A quadrilateral is a four-sided polygon.

A parallelogram is a quadrilateral which has its opposite sides parallel.

A rectangle is a parallelogram which has its angles

right angles. (O-42)

A square is a quadrilateral that is both equilateral and equiangular. (O-43)

A diagonal of a quadrilateral is a straight line joining two opposite vertices.

A diagonal of a polygon is a line joining the vertices of two non-adjacent angles.

The diagonals AD, BE, and CF of a regular polygon are equal. (See Figure 34.) (O-44)

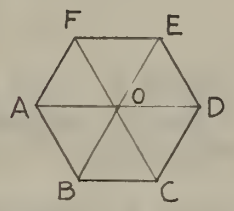


Figure 34-
A regular hexagon.

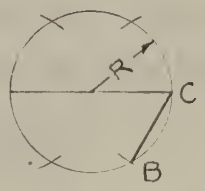


Figure 35 - The radius as the side of a regular inscribed hexagon.

The diagonals of a regular hexagon divide the hexagon into six equilateral triangles. (See Figure 34) (O-45)

The vertex angle of a regular polygon is the angle formed by the two sides of the polygon, as $\angle AFE$ in Figure 34. (O-46) The central angle of a regular polygon is an angle that has the center of the polygon for its vertex such as $\angle BOC$ or $\angle AOC$ in Figure 34. (O-47)

The angles of any triangle add up to 180°. (O-48)

<u>The regular hexagon</u>.-- The radius of a circle can be marked off on the circumference of a circle exactly six times and this applies to any size circle. See Figure 35.

The radius R equals the chord BC.

Thus a regular hexagon may be inscribed in a circle by marking off the radius of that circle six times on the circumference and connecting the points. (O-49) A regular hexagon may be constructed when only the length of one side is known. (O-50) A regular hexagon may be inscribed or circumscribed about a circle. (O-51) A regular hexagon has a long and a short diameter. See Figure 36. AB is the long diameter and is the diameter of the circumscribed circle. CD is the short diameter and does not touch the circle. CD is referred to as the distance across flats. (O-52)

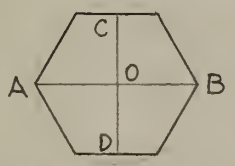


Figure 36 - A regular hexagon, long and short diameters.

Hexagon inscribed in a circle.--

1. Long diameter horizontal (Compass method)- Using points A and B as centers and OA as a radius, describe arcs at E, F, H, and K. Connect the points as shown in Figure 37. (The radius used as a chord six times on circumference) (O-53)

2. Long diameter vertical- Same as above, but with hexagon turn as shown in Figure 38. (O-54)

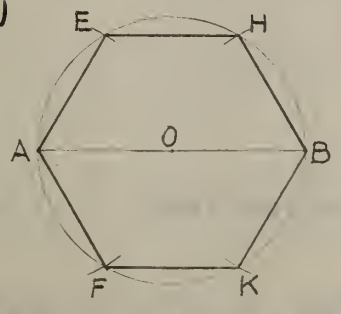


Figure 37 - Inscribed hexagon, long diameter horizontal (compass method)

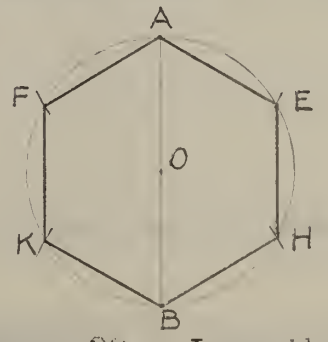


Figure 38 - Inscribed hexagon, long diameter vertical (compass method)

3. Long diameter horizontal (Draftsman's method)- With 30°-60° triangle and T-square, draw the lines in the order shown. See Figure 39. (0-55)

4. Long diameter vertical (Draftsman's method)- With 30°-60° triangle and T-square, draw the lines in the order shown. See Figure 40. (0-56)

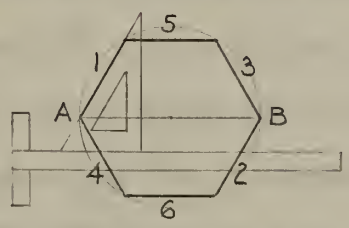


Figure 39 - Inscribed hexagon, long diameter horizontal (draftsman's method).

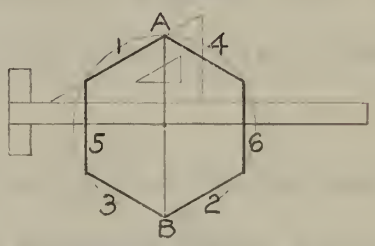


Figure 40 - Inscribed hexagon, long diameter vertical (draftsman's method).

5. If given the long diameter, a regular hexagon may be constructed by the use of T-square and 30°-60° triangle. Example:- "Draw lines with the 30°-60° triangle (and T-square) in the order shown."[1/] No compass is required. See Figure 41. (0-57)

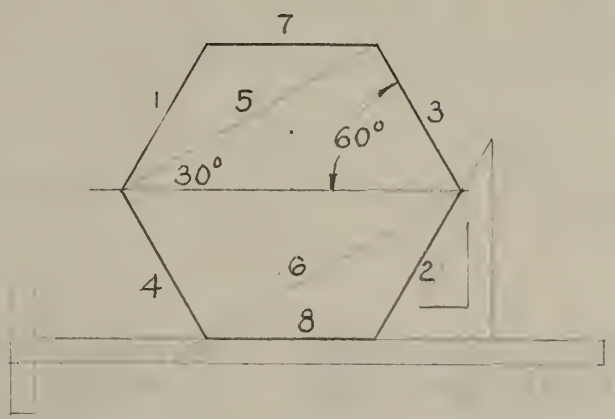


Figure 41 - Constructing hexagon without use of compass.

1/ Thomas E. French, Engineering Drawing, McGraw-Hill Book Company, Inc., New York, 1941, p. 63.

Hexagon circumscribed about a circle.--

1. Long diameter horizontal-

A hexagon may be circumscribed about a circle by the use of the 30°-60° triangle and T-square, by drawing lines tangent to the circle, as shown in Figure 42. The exact points of tangency are found by drawing the vertical center line and the two 30° lines through the center of the circle. (0-58)

2. Long diameter vertical-

A hexagon may be circumscribed about a circle by the use of the 30°-60° triangle and T-square, by drawing lines tangent to the circle as shown in Figure 43. The exact points of tangency may be found by drawing the horizontal center line and the two 60° lines through the center of the circle. (0-59)

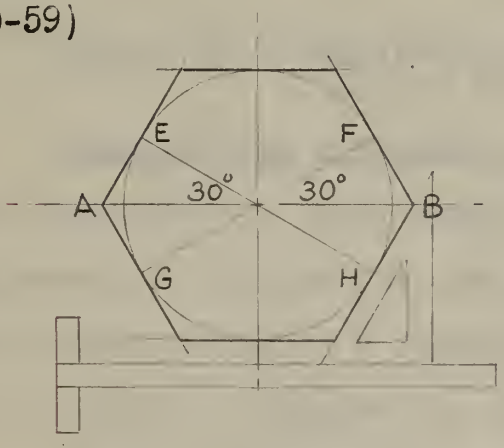


Figure 42 - Circumscribed hexagon, long diameter horizontal.

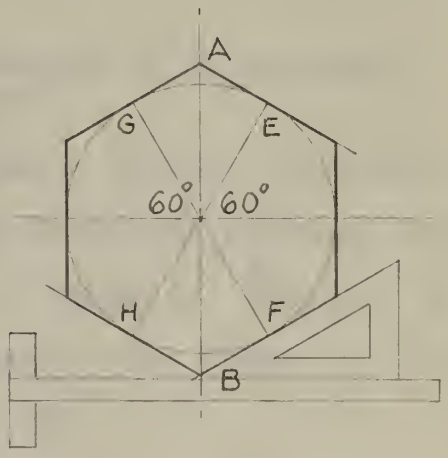


Figure 43 - Circumscribed hexagon, long diameter vertical.

The hexagon as an important figure in mechanical drawing.-- The hexagon is useful in the drawings of hexaonal prisms, hexagonal glands, and American Standard Bolts and

Nuts. Figure 44 shows the hexagon as applied to the drawing of a Bolt Head. (O-60)

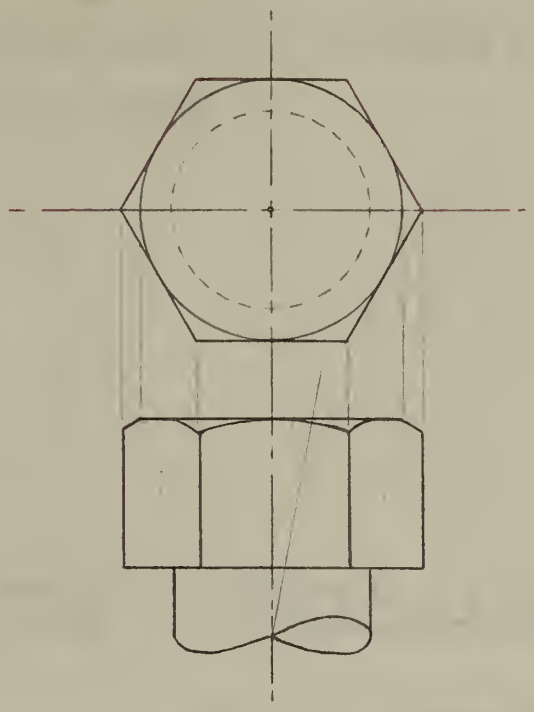


Figure 44 - Application of hexagon to an American Standard Bolt Head.

Constructing a regular octagon.-- Gieseke, Mitchell, and Spencer[1/] in their textbook on Technical Drawing, have an excellent chapter on Geometry of Technical Drawing. In the constructing of a regular octagon, they offer the following methods in Figures 45, 46, and 47.

1. The circumscribed square method.

"With the corners of the given square as centers, and with half the diagonal as radius, draw arcs cutting the sides as shown. Join the points thus found." (O-61)

1/ Frederick E. Gieseke, Alva Mitchell, and Henry C. Spencer, Technical Drawing, The Macmillan Company, New York, 1936, p.57

2. The inscribed circle method.

"Using the 45° triangle and the T-square, draw the sides of the octagon tangent to the given circle as indicated in Figure 46." (O-62)

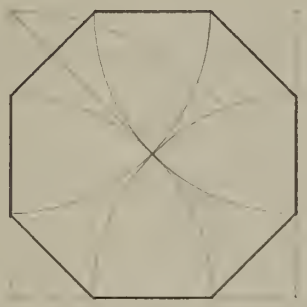


Figure 45 - To construct a regular octagon within a square.

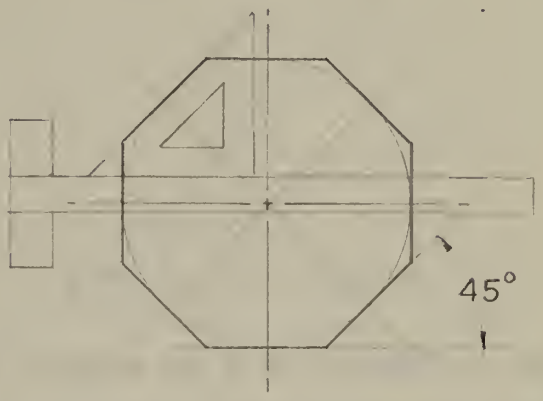


Figure 46 - A regular octagon, circumscribed about a circle.

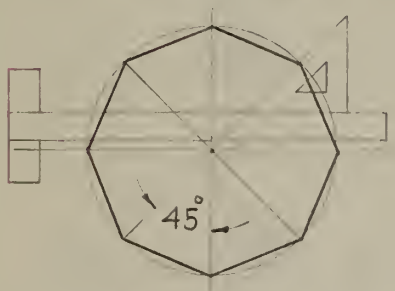


Figure 47 - A regular octagon inscribed in a circle.

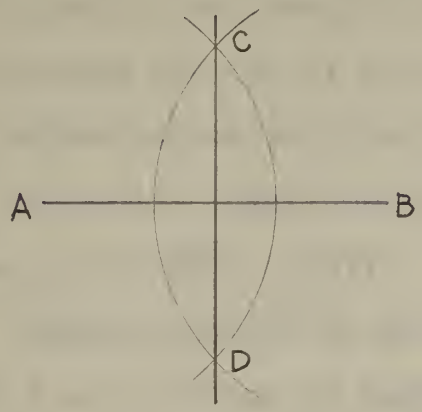
3. The circumscribed circle method.

"Draw four diameters 45° apart as shown. The points of intersection of these diameters and the given circle are the vertices of an inscribed octagon." (O-63)

<u>To bisect a line, AB</u>.-- Bisect means to divide into two equal parts. Using A and B as centers and with a radius greater than ½AB, draw arcs intersecting at C and D. (See Figure 48) CD will then bisect AB. (O-64)

<u>To bisect an angle, ∠ ABC</u>.-- Using B as a center and with any convenient radius, draw an arc intersecting the sides AB and BC. (See Figure 49) Using these intersections,

X and Y, centers, draw the arcs intersecting at Z. BZ will then bisect the ∠ABC. (0-65)



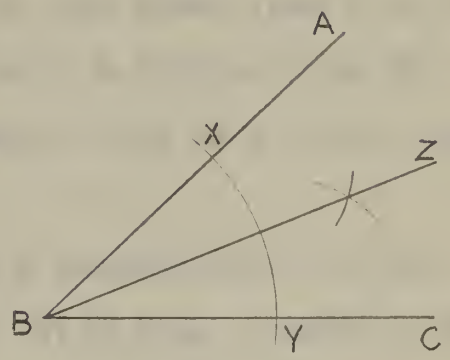


Figure 48 - To bisect a line. Figure 49 - To bisect an angle.

To construct a perpendicular to a line AB at a given point P.-- Using P as a center and a convenient radius, draw the arc as shown, intersecting the given line at C and D. With C and D as centers and with a convenient radius, draw arcs intersecting at E. EP will be the required perpendicular. A perpendicular to a line makes an angle of 90° with the line, Figure 50. (0-66)

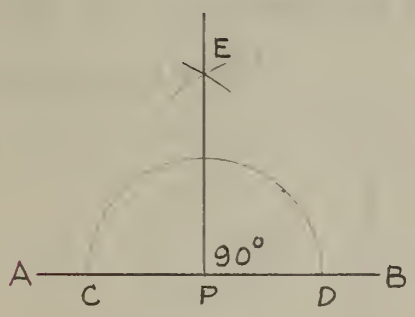


Figure 50 - To construct a perpendicular to a line at or near the middle of the line.

To erect a perpendicular to line AB, (at B) at the end of the line, Figure 51.-- Klenke and Hayes[1/] in their text on Elementary Mechanical Drawing set forth the following directions: "From an assumed point C as a center and a

1/ Op. cit. p. 71

radius CB, describe an arc of indefinite length cutting the line AB, thus locating the point E. From the point E, draw a diagonal line through the point C and prolong it until it intersects the arc at point D. A line drawn from D to B will be perpendicular to AB at the point B." DB will be 90° to AB. Any angle inscribed in a semi-circle is a right angle or an angle of 90°. (O-67)

Another method of erecting a perpendicular at the end of a line is shown in Figure 52. With A as a center and a convenient radius, draw an arc as shown. With the same radius and starting at D, mark off on the arc two points E and F. Using E and F as centers and any convenient radius, draw arc intersecting at G. GA will be the required perpendicular. (O-68)

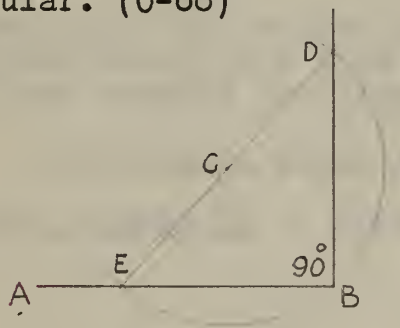


Figure 51 - To construct a perpendicular to the end of a line; Case I.

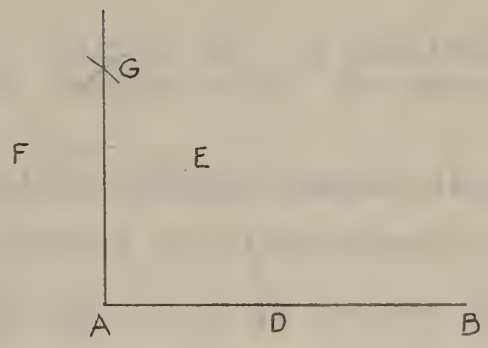


Figure 52 - To construct a perpendicular to the end of a line; Case II.

<u>To construct a perpendicular to line AB from point P, outside the line AB. Figure 53</u>.-- With P as a center and with a radius greater than the distance from P to AB, describe an arc cutting CB at E and F. With E and F as centers and with a radius greater than $\frac{1}{2}$EF, draw the arcs intersect-

ing at G. PG will be the required perpendicular. (O-69)

To construct a square; given the base AB, Figure 54.-- Construct EA perpendicular to AB. See (O-67, 68) page 39. Using A as a center and a radius equal to AB, draw the arc as shown intersecting AE at D. With B and D as centers and with the same radius (AB), draw arc intersecting at C. Connect DC and BC. ABCD will be the required square. All sides of a square are equal and all angles are right angles.(O-70)

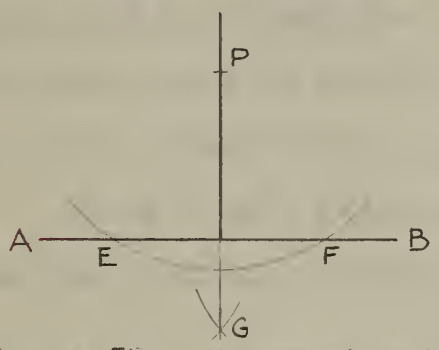


Figure 53 - To construct a perpendicular to a line from a point outside the line.

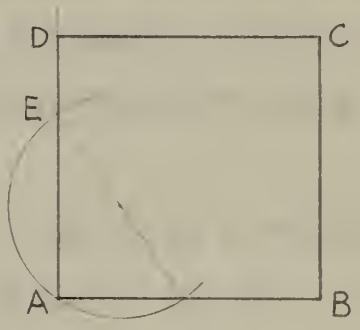


Figure 54 - To construct a square; given the base.

To divide a given line, AB, into any number of equal parts, Figure 55.-- Draw a line AC at a convenient angle to line AB. If it is desired to divide AB into seven equal parts, then mark off on AC, seven spaces using the dividers (set to a given unit). Starting at A, the seventh unit will stop (in this case) at D on line AC. In this problem 3/8" was a convenient unit to use. Any unit of approximately that size could have been used. Join D with B and through points 6, 5, 4, 3, 2, and 1 draw

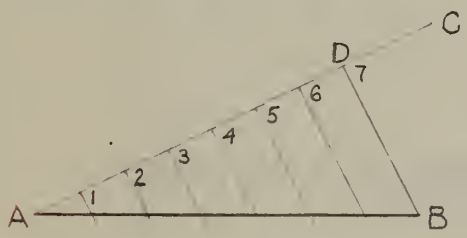


Figure 55 - To divide a line into any number of equal parts.

lines parallel to DB. AB will then be divided into seven equal parts. See (O-7) pages 8 and 9. (Lines which however far extended will not meet, are parallel.)

AD and AB may be thought of as transversals. Then, if three or more parallel lines cut off equal segments on one transversal, they cut off equal segments on every transversal. (O-71)

To draw an arc of a circle through three given points, A, B, and C, Figure 56.-- Connect the points AB and BC. Bisect the lines AB and BC, having the bisecters intersect at point O. (O-64) (page 41)

Using O as a center and OA, OB or OC as a radius, draw the required arc through points A, B and C. (O-72)

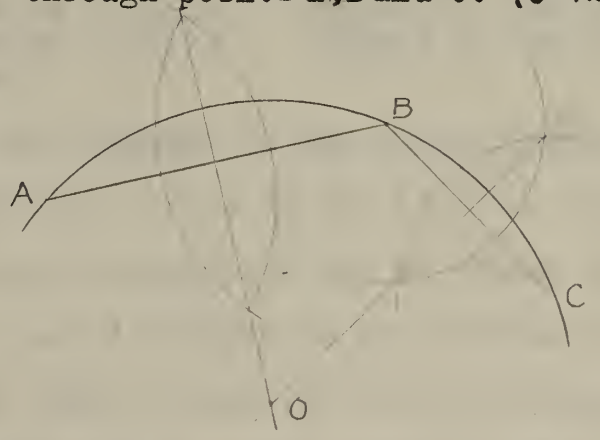


Figure 56 - To draw an arc of a circle through three given points.

To draw a line tangent to a circle from an external point P: Figure 57.-- Connect the outside point P with the center of the circle. Bisect the line OP, obtaining its midpoint, A. With A as a center and with radius AO, draw the semi-circle intersecting the circle O at B. BP will be the

required tangent and point B will be the exact point of tangency. The geometric principles envolved are:- A tangent to a circle has but one point in common with the circle. A tangent to a circle makes a right angle with the radius drawn to that point. Any angle inscribed in a semi-circle is a right angle. (0-73)

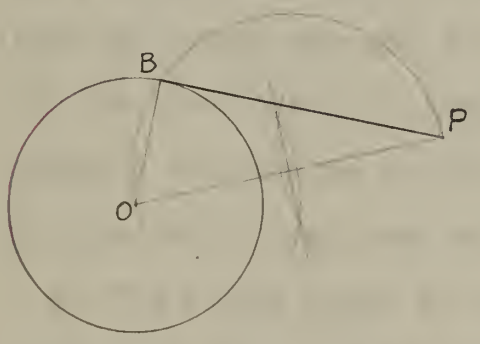


Figure 57 - To draw a tangent to a circle from an outside point.

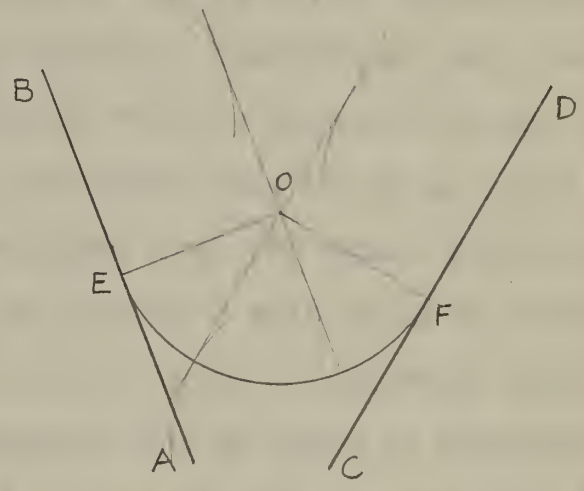


Figure 58 - To draw an arc tangent to two given lines.

<u>To draw an arc tangent to two given straight lines, Figure 58</u>.-- Given the lines AB and CD. (In this problem a radius of 7/8" for the required arc is used). Construct a line parallel to and 7/8" from AB and another parallel to and 7/8" from CD. Where these two lines intersect will be the center O of the required arc. Using O as a center and a radius equal to the perpendicular distance from O to CD, draw the arc as shown meeting AB at E and CD at F. This arc EF is tangent to the two given lines AB and CD. The exact points of tangency may be found by dropping perpendiculars from O to AB and from O to CD. (0-74)

To draw an arc tangent to a given straight line and to a given arc, Figure 59.-- Given the straight line AB and the arc of any convenient radius with center at O. (In this figure the required arc of tangency is to have a radius of $1\frac{1}{4}$" and the given arc a radius of 7/8".) First, draw line CD parallel to and $1\frac{1}{4}$" from AB. Secondly describe an arc, having a radius of 2-1/8". This arc will be parallel to and $1\frac{1}{4}$" from the given arc and will intersect line CD at E. Point E will be the center of the required arc. The exact points of tangency can now be found. Join point O with point E. Where OE intersects the given arc is one point of tangency. Mark it F. The other point of tangency can be found by dropping a perpendicular from point E to line AB. Mark it G. With E as a center and with a radius of $1\frac{1}{4}$", draw the required arc of tangency from F to G. (O-75)

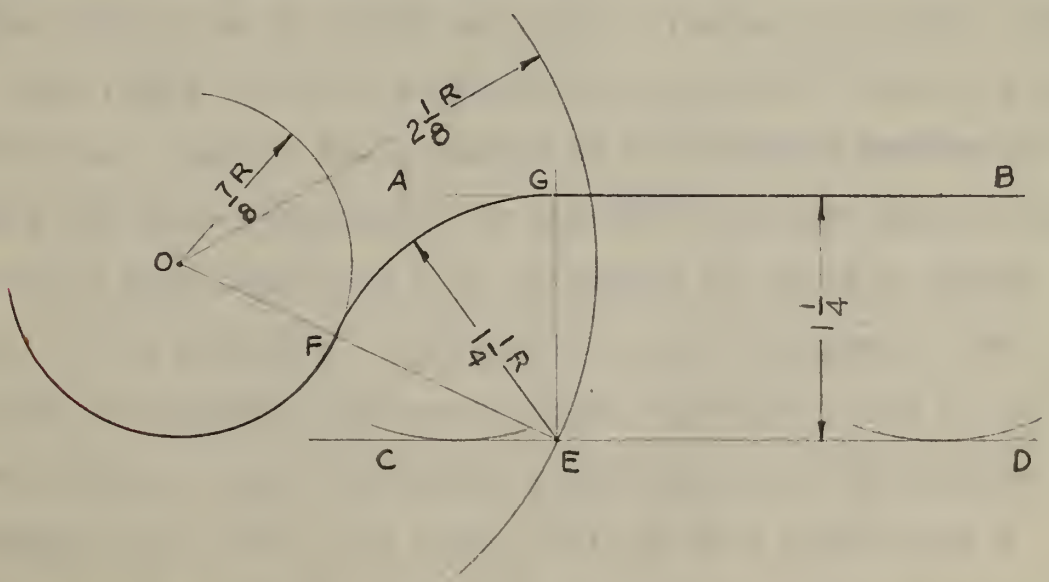


Figure 59 - To draw an arc tangent to a given straight line and to a given arc.

To draw an arc tangent to two given arcs. Figure 60.--

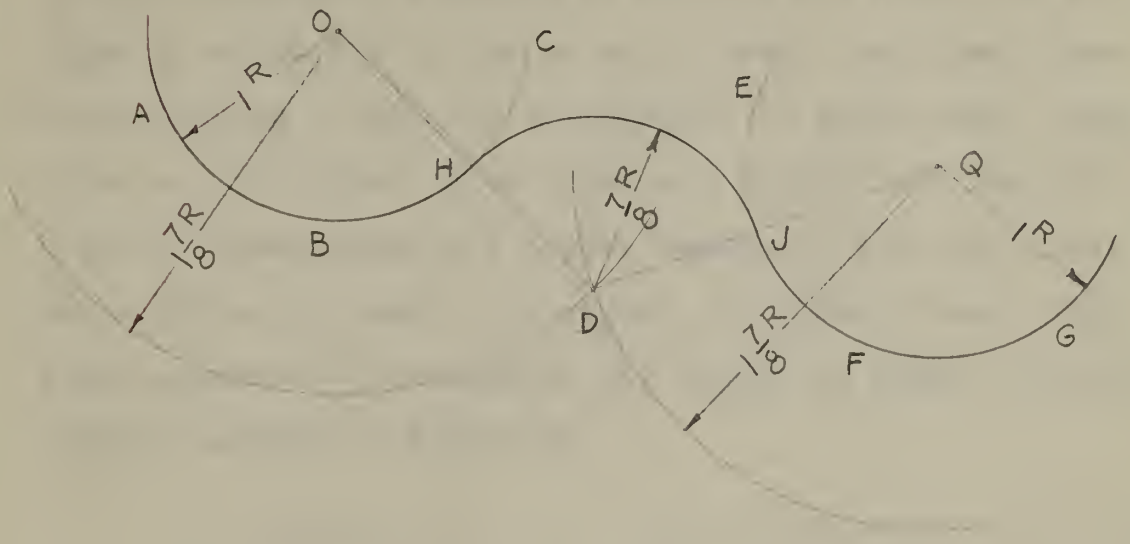


Figure 60 - To draw an arc tangent to two given arcs. For convenience, the arc of tangency in this problem has a 7/8" radius. The two given arcs ABC and EFG have radii as shown. With O as a center and with a radius of 1-7/8", draw an arc. (This arc will be parallel to and 7/8" from arc ABC.) With Q as a center and a radius of 1 7/8", draw another arc. (This arc will be parallel to and 7/8" from arc EFG.) The two arcs thus described will intersect at point D, which will be the center of the required arc of tangency. The points of tangency may now be found by joining the center O with point D and the center Q with point D. The points of tangency are H and J as shown. With D as a center and a radius equal to 7/8", draw the required arc of tangency from H to J. (O-76)

Orthographic Projection

Orthographic projection simplified.-- Orthographic projection drawing is a method of showing the true size and shape of an object in two or more views, the views themselves having a definite arrangement to each other. Separate faces of the object to be drawn are studied and separate views of these faces are drawn. Generally the top, front and right side views of an object are drawn, these views being obtained by looking at the object as shown in the perspective sketch of Figure 61.

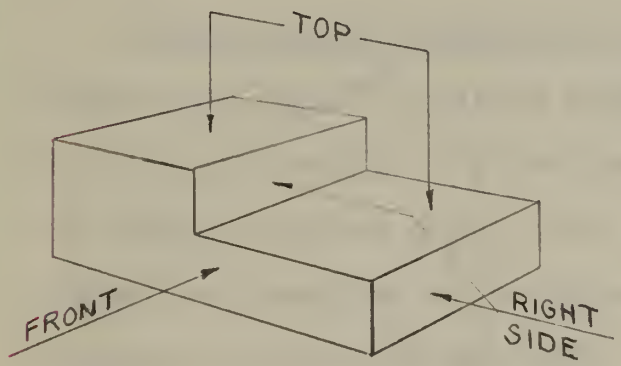


Figure 61 - A perspective drawing.

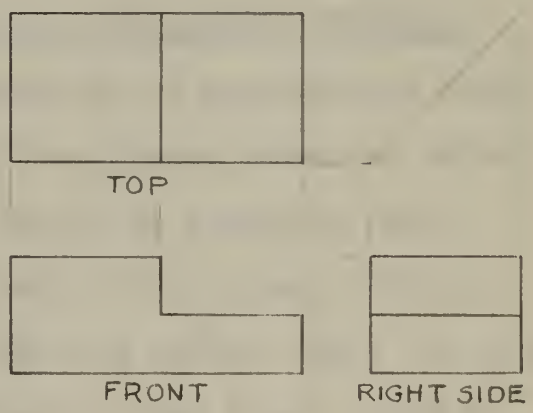


Figure 62 - An orthographic drawing.

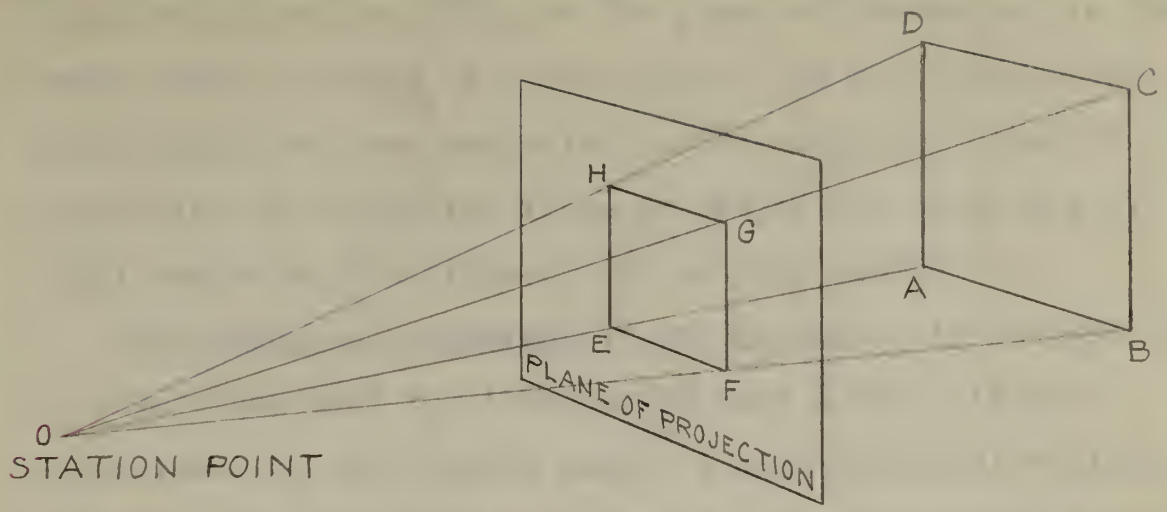
Figure 62 shows how the top, front and right side views would be arranged in an orthographic drawing. It should be observed that of these two drawings, the perspective sketch does not show the true size, shape and location of the various parts of the object. (O-77)

What has been actually done is to represent on a flat

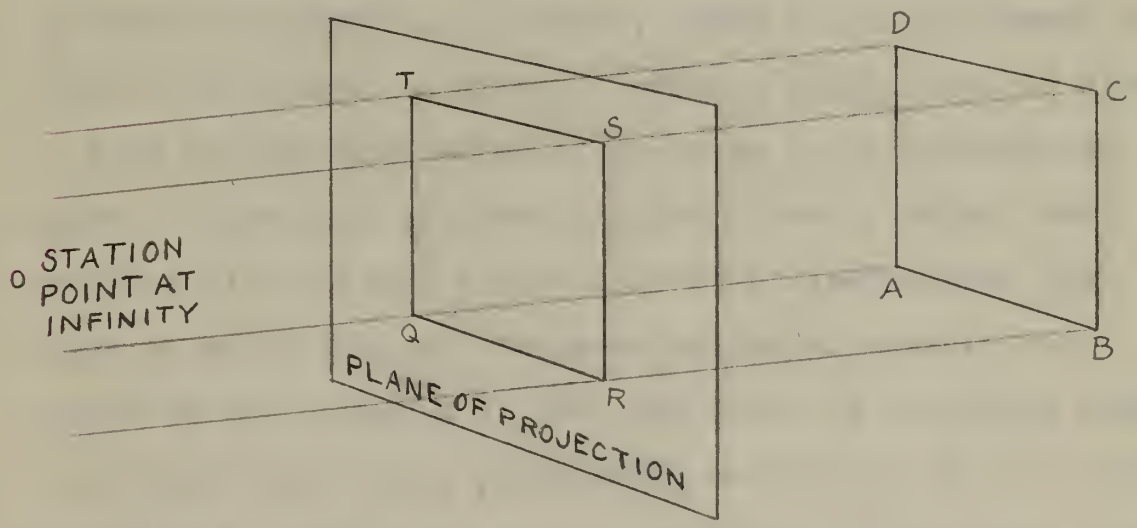
piece of paper of only two dimensions (length and width), a three-dimensioned object having length, width, and thickness. It can be observed in Figure 62 that (1) the length of the top view equals the length of the front view, (2) the top view is directly above the front view, (3) the height of the front view equals the height of the right side view, (4) the right side view is directly in line with and to the right of the front view, (5) the vertical height of the top view equals the horizontal width of the side view. These facts hold true for all three-view orthographic drawings. (0-78)

Comparison of perspective and orthographic drawing.--Klenke and Hayes[1/] give an explanation of perspective drawing that is helpful: "A perspective drawing shows an object as viewed from one point, the eye of the observer; and therefore shows two or three sides of the object. The eye remains in one fixed position, and the radial lines are the lines of sight to the - - - corners of the block." Figure 63(a) shows a perspective drawing of the plane ABCD. Point O is the station point or the point from which the observer looks at the object. The perspective drawing, EFGH on the plane of projection will be much smaller than the object ABCD, because the projecting lines or projectors do not form right angles with the plane of projection.

1/ Op. cit. pp. 92, 95.



(a) Perspective



(b) An orthographic projection

Figure 63 - Comparison of a perspective and an orthographic projection[a/].

Figure 63 (b) shows an orthographic projection of the plane ABCD. The projectors do not converge on the observer, but are parallel. Theoretically they would meet at infinity.

a/ Adapted from Giesecke, Mitchell, and Spencer Technical Drawing - op. cit. p. 110.

Thus the projection QRST, on the plane of projection is the exact size and shape of the object or the plane ABCD. The object ABCD has been projected to the imaginary plane of projection by projecting lines or projectors which are at right angles to the plane of projection. (O-79)

The theory of orthographic projection.-- It is important to understand that the three views have a definite set arrangement on the drawing paper. A more technical explanation for the arrangement of views will better describe what is meant by orthographic projection. "The phrase 'to project' as used in geometry and drawing, means to throw forward in a given direction or to extend forward a point, line or plane to some surface upon which it is going to be represented. Hence, in (mechanical) drawing, the corners, edges, and surfaces of an object are said to be projected upon the plane on which they are represented."1/ For example, in Figure 64 the corner A of the step block is projected along the dotted line to the plane HVST, and the point a' is said to be the projection of A upon the plane. "The dotted line along which the point is supposed to be moved is called a projecting line. The plane upon which the drawing or projection is made is called a plane of projection."2/

1/ Randolph P. Hoelscher and Arthur B. Mays, Basic Units in Mechanical Drawing Book 1, John Wiley & Sons, Inc., New York 1933, pp. 62 and 63.

2/ Ibid.

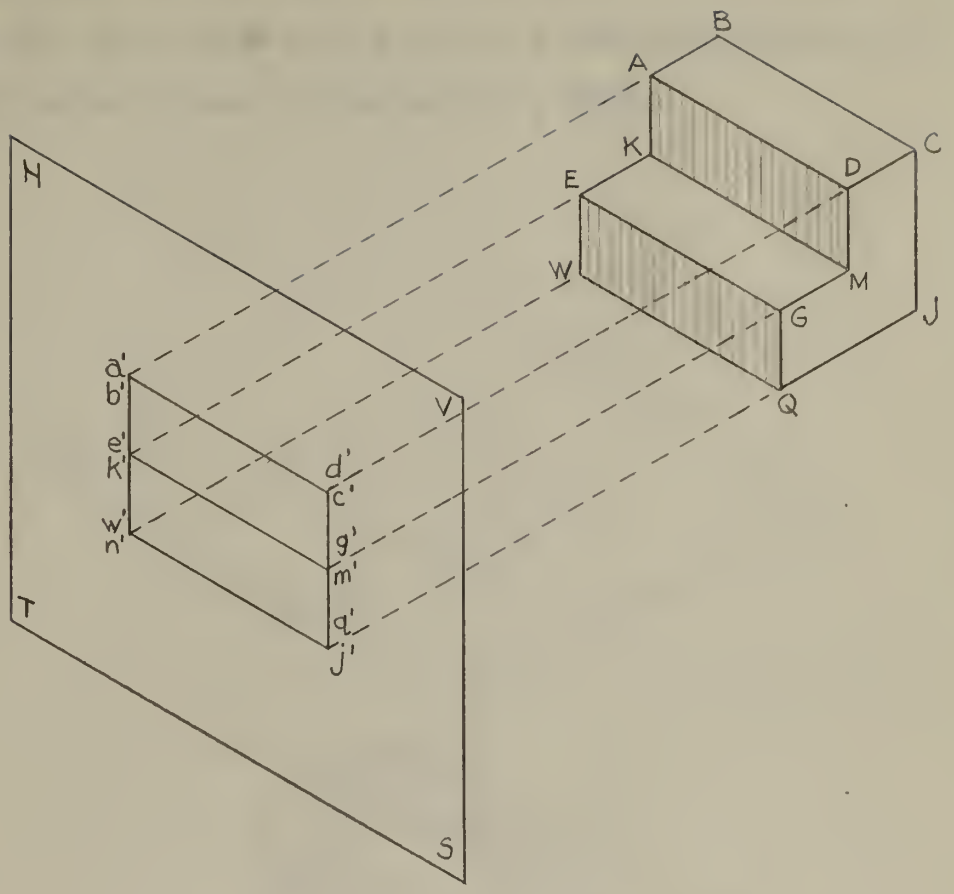


Figure 64 - An orthographic projection on the vertical plane.

The plane of projection is imaginary, transparent, and vertical. The two front vertical surfaces (ADMK and EGQW) of the step block are shown as one view (a'd'q'w') on the projection plane. The projecting lines make angles of 90^{o} with the plane of projection and are therefore perpendicular to the plane of projection. Projections of this type are called orthographic projections. (0-80)

In like manner the top surfaces of the step block may be

projected to a transparent, imaginary horizontal plane. See Figure 65. The projecting lines are now perpendicular to the horizontal plane of projection, WXYZ.

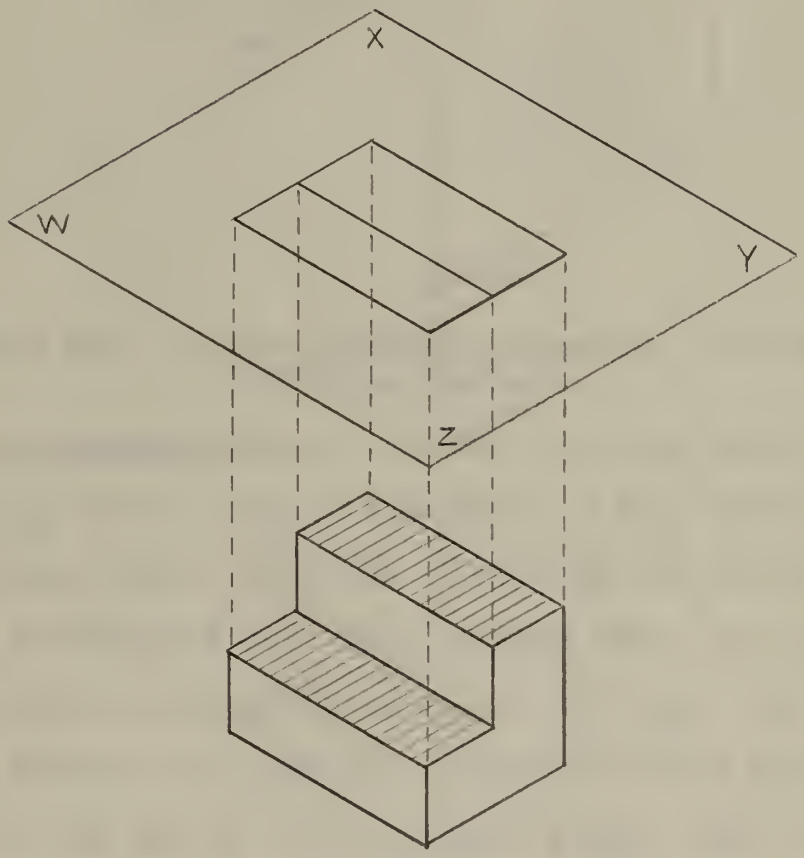


Figure 65 - An orthographic projection on the horizontal plane.

In Figure 66, the right side surface has been projected to a right side vertical or profile plane, LMPQ.

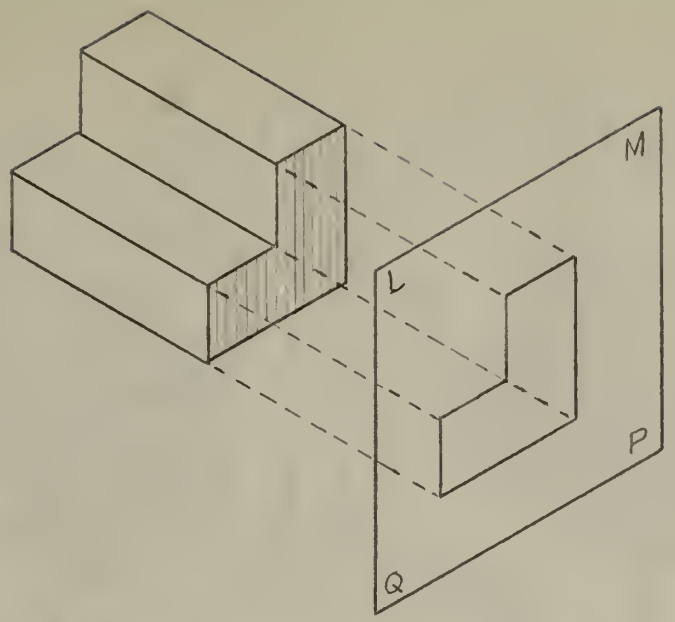
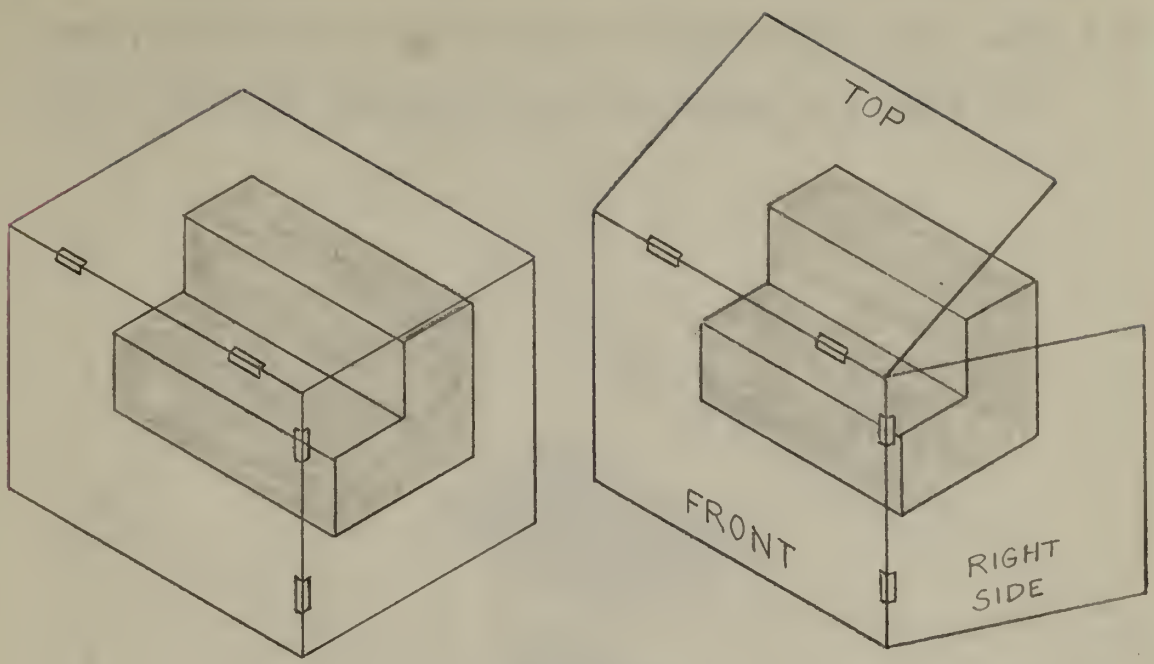


Figure 66 - An orthographic projection on the right vertical plane.

The transparent box.-- In order to show these three views, (top, front and right side) on a flat sheet of paper we can imagine that the step block has been placed inside a transparent box. This is made "with the top hinged to swing directly over the front and the right side hinged to swing directly to right of the front".[1/] See Figure 67. The top of the box is the horizontal plane. The front of the box is the front vertical plane, and the right side of the box is the right vertical plane. Thus the three planes of projection will, when the box is opened, take definite set positions in relation to each other. See Figure 68. (O-81)

1/ Suggested Unit Course in Blue Print Reading for Beginners in Machine Shop Practice, Vocational Education Program for National Defense Industries, The University of the State of New York, The State Education Department, Bureau of Industrial and Technical Education, 1942 Edition, p. 1.

Boston University
School of Education
Library



(a) Box closed (b) Box partly opened

Figure 67 - The planes of projection as the sides of a hinged, rectangular, and transparent box.

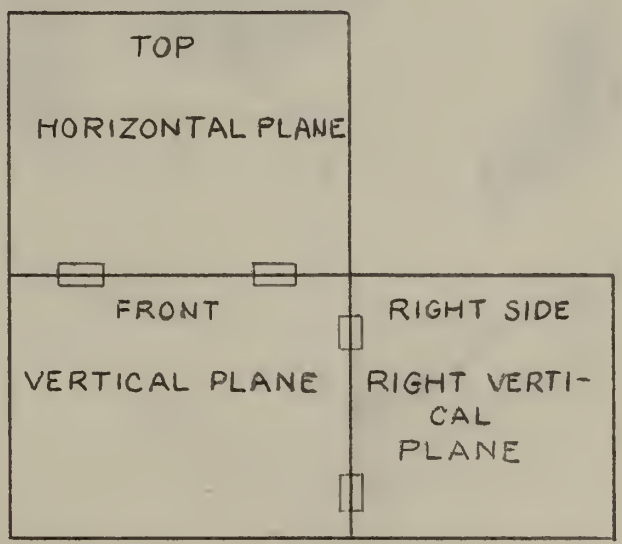


Figure 68 - The box opened showing the arrangement of the three planes to each other.

Likewise, the three faces of the step block having been projected to these planes (Figure 69) will, when the box is opened, take positions as shown in Figure 70.

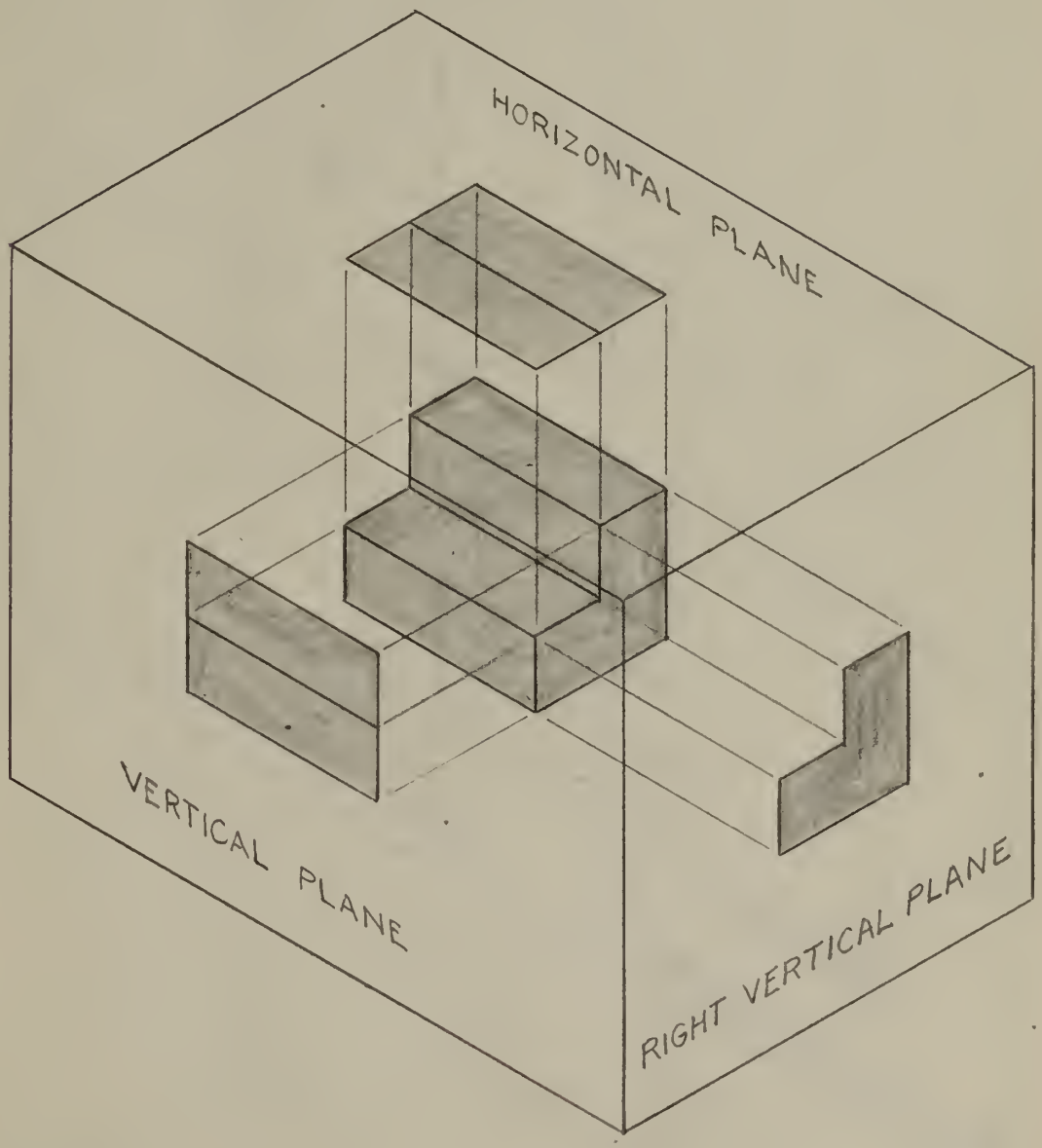


Figure 69 - The top, front and right side surfaces of the step block projected to the horizontal, vertical and right vertical planes respectively.

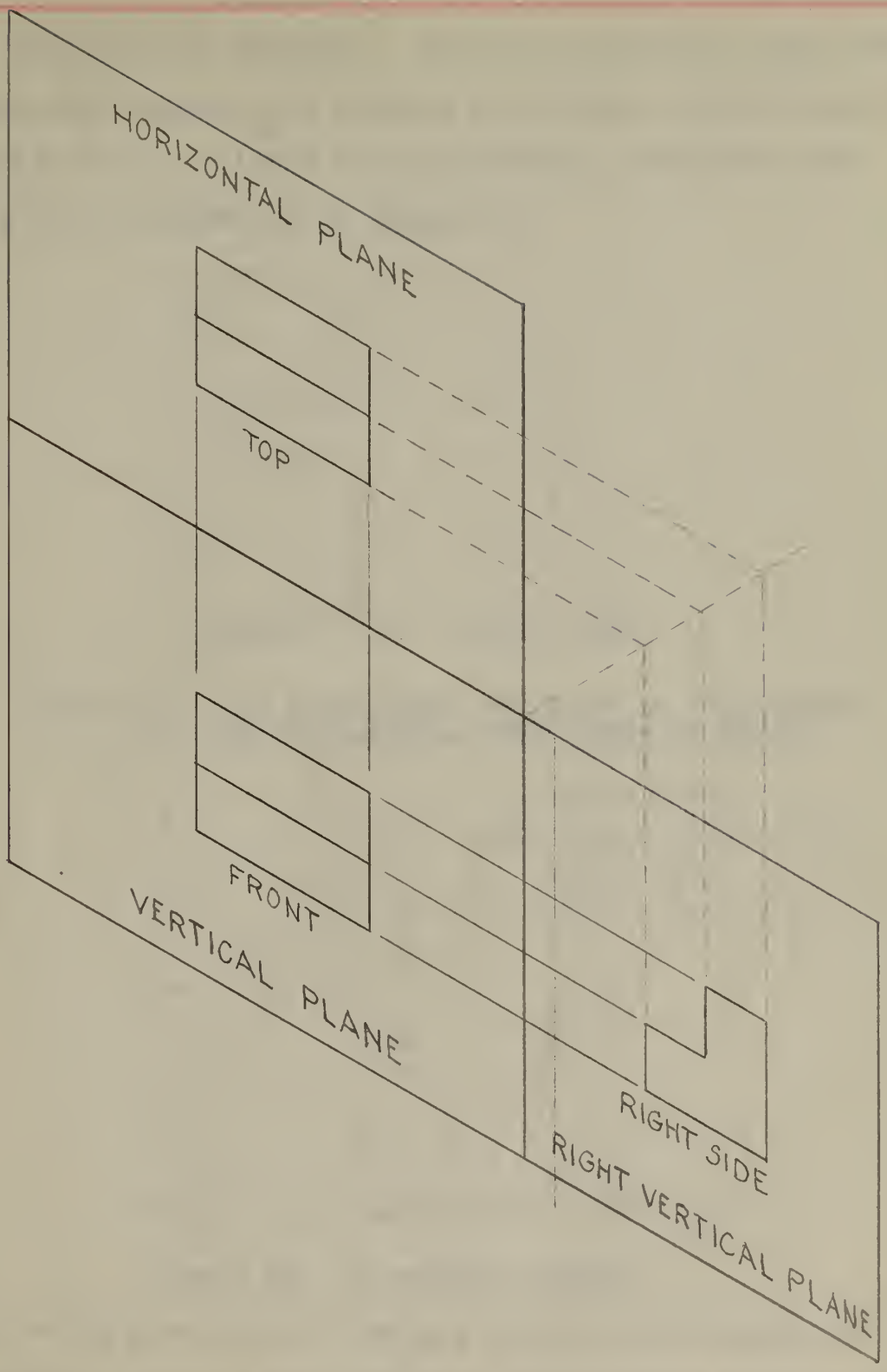


Figure 70 - The box opened showing the arrangement of the three views to each other.

The finished drawing.-- When the projection lines and planes are removed, the drawing will appear as in Figure 71. To make this a finished working drawing, dimensions and notes will be added as in Figure 72.

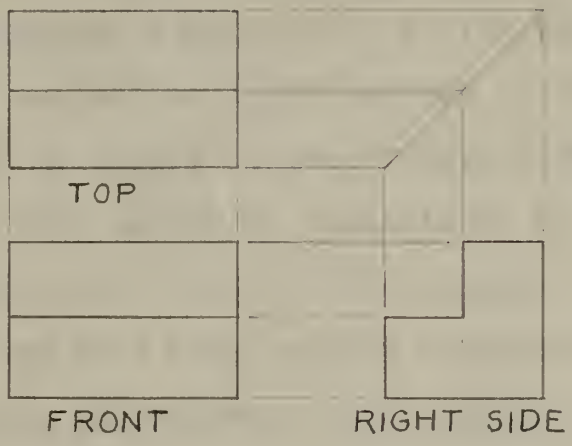


Figure 71 - The arrangement of views as they appear on a two-dimensional flat piece of paper.

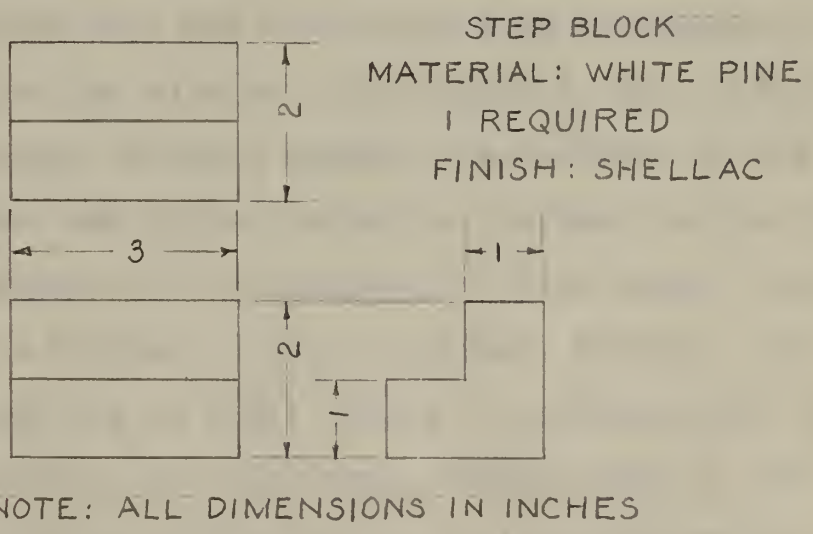


Figure 72 - A working drawing.

This is the basis of all two and three view orthographic drawings. It can be observed from the finished drawing that "the top view is directly above the front, and the side

view is at the right and on a line with the front view."[1] The vertical height of the top view is equal to the horizontal width of the side view. (O-82)

Orthographic projection defined.-- In French's[2] Engineering Drawing, a definition serves well to summarize, "Orthographic projection is the method of representing the exact shape of an object in two or more views on planes generally at right angles to each other, by extending perpendiculars from the object to the planes." The perpendiculars are what we have been calling "projecting lines" and these projecting lines are at right angles to the planes of projection. (O-83)

An orthographic projection of an oblique surface.-- In the step block that has heretofore been illustrated, the projecting lines are also at right angles to the surfaces of the step block, but only because the surfaces of the step block have been either horizontal surfaces or vertical surfaces. In Figure 73, the projecting lines cannot be at right angles to beveled (oblique) surface. However, the projecting lines are at right angles or perpendicular to the plane of projection. To illustrate, surface ABCD on the object will be foreshortened on the vertical projection plane, QRST, and will be represented by the rectangle

1/ Youngberg, Edwin S. - "Mechanical Drawing for High Schools", Pitman Publishing Corporation, New York, 1938, p.20

2/ Op. cit. p. 85.

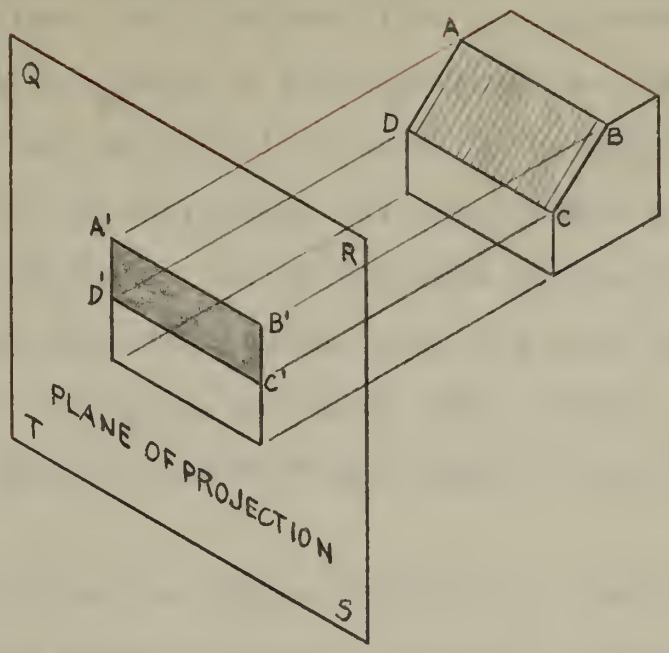


Figure 73 - Projection of an oblique surface. A'B'C'D'. Projection lines AA', BB', CC', and DD' will be perpendicular to the plane QRST and not perpendicular to surface ABCD. (O-84)

Choice of views.-- Usually three views will be the maximum number of views to represent an object. If all the views were drawn, they would appear as in Figure 74.

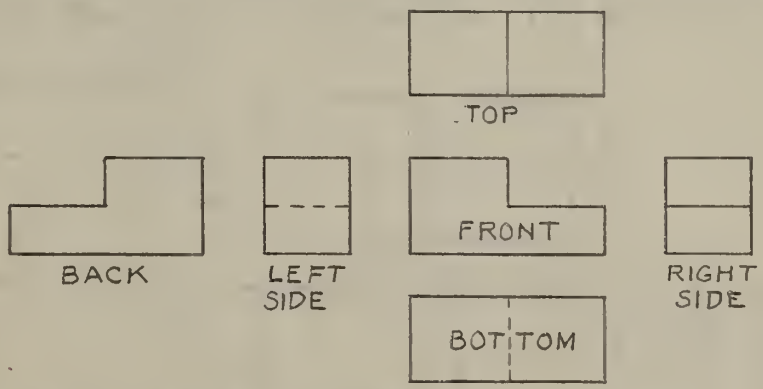


Figure 74 - The six views and their usual arrangement.a/

a/ Adapted from Orthographic Projection, a printed sheet on Tentative Standards by the Mechanical Drawing Association of New England, 1939-1.

It is obvious that the back view is the same shape as the front. The left side is the same shape as the right side, except that in the left side view the edge representing the step cut is invisible. Invisible edges are represented by dotted lines. The bottom view is the same as the top except that the edge representing the step cut in the bottom view is invisible. Actually then, three views sufficiently describe the size and shape of the object. (0-85)

Some objects are so shaped that four views are necessary to make the drawing legible. Instead of showing only the top front and right side views, a left side view is added. In this way many dotted lines are eliminated. To illustrate, Figure 75 is a 3-view drawing and Figure 76 is the same drawing with 4 views. Much of the dotted line work shown in right side view of Figure 75, has been eliminated by drawing the additional left side view of Figure 76. This is standard drafting room practice. The 4-view drawing is a lot clearer. (0-86)

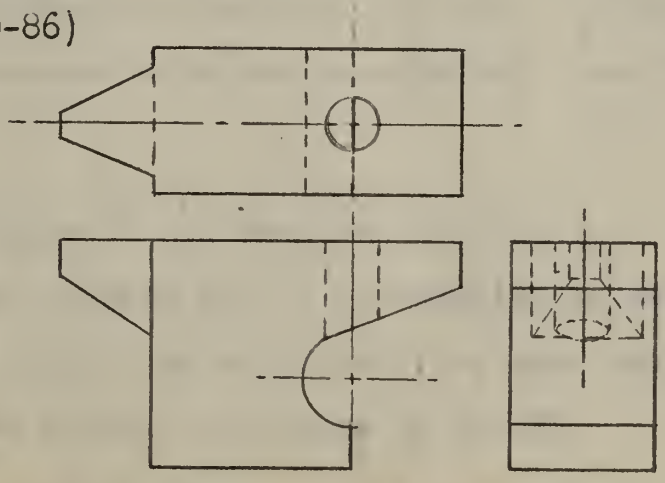


Figure 75 - A three-view drawing.

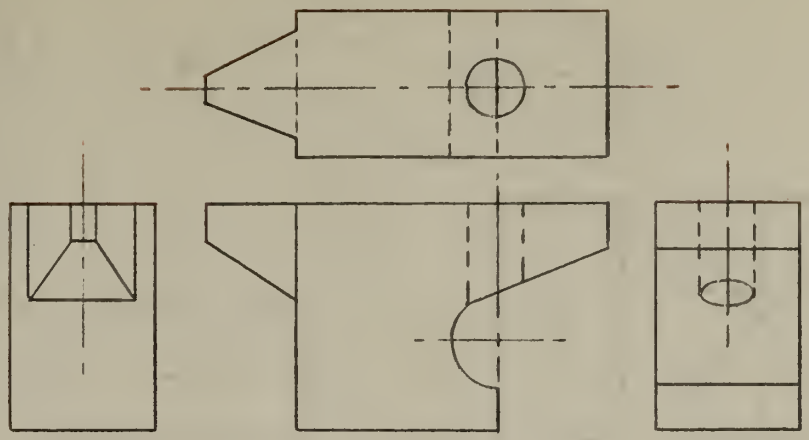


Figure 76 - A four-view drawing for clearness.

Often two views will fully describe the object, especially if the contour is that of the drawing shown in Figure 77. A side view of this object would be unnecessary. (0-87)

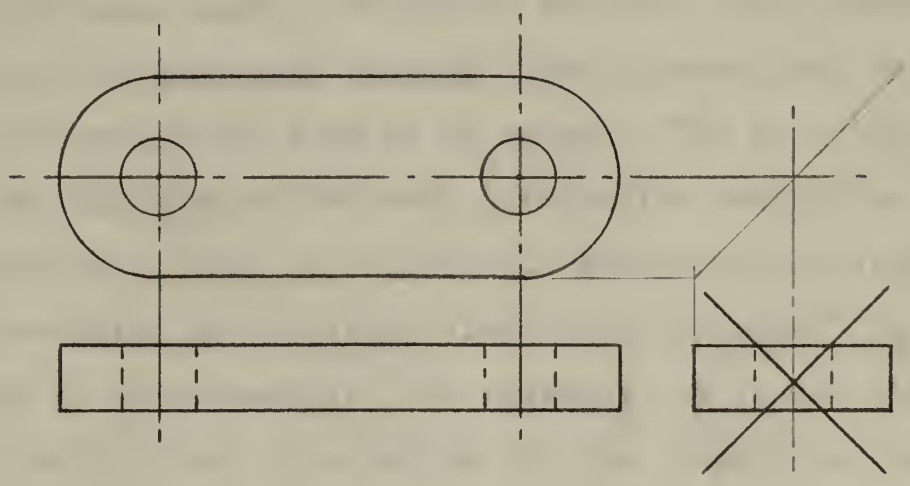


Figure 77 - A two-view drawing.

Cylindrical objects may be represented in two views also because a third view would have the same shape as one of the other two views. See Figure 78 and 79.

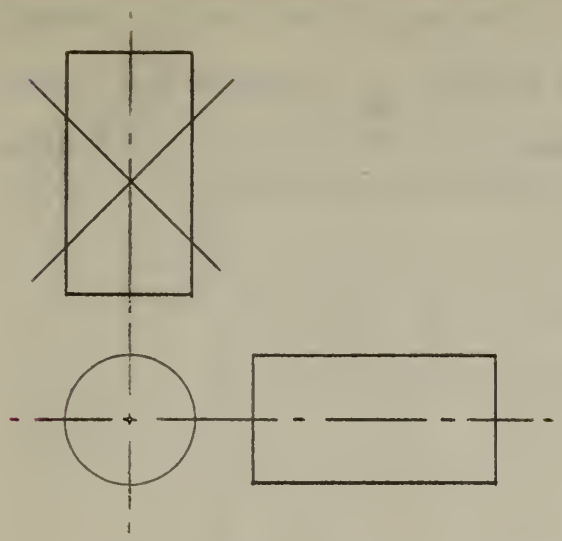


Figure 78 - A two-view drawing.

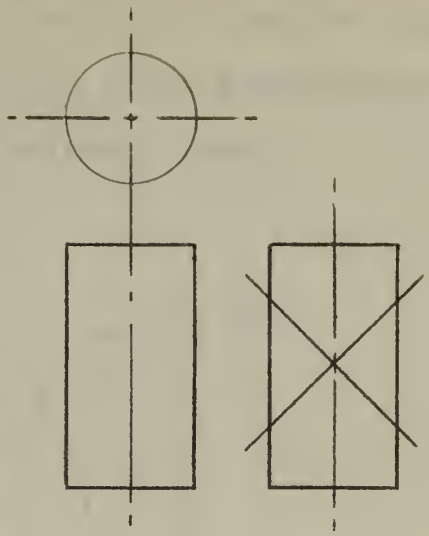


Figure 79 - A two-view drawing

In Figure 78, the top view is eliminated and in Figure 79 the side view is eliminated. (0-88)

The principal view.-- Giesecke, Mitchell, and Spencer[1/] in their text on Technical Drawing offer an excellent explanation of the principal view of an object: "The principal view is that which gives the most information concerning the characteristic form of the object. The principal view should be selected as the front view in the drawing." In the drawing of an automobile, for instance, it is the side of the automobile that is selected for the front view, because it is that view which looks most like an automobile and which conveys the most information. (0-89)

Often the amount of space that a drawing will occupy on a paper is important in the selection of views. For this

1/ Op. cit. - p. 120.

reason it is wise to select for the front view the largest view. For example, in Figure 80, the three views occupy an area 4" by 6", if 1" is allowed between views.

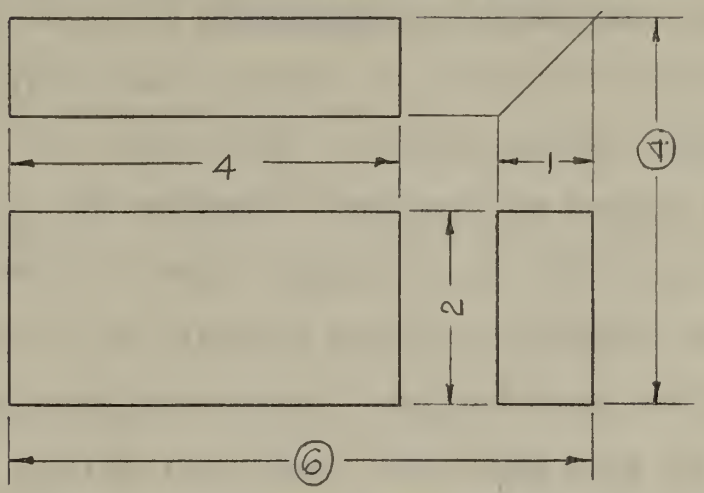


Figure 80 - The front view as the largest view.

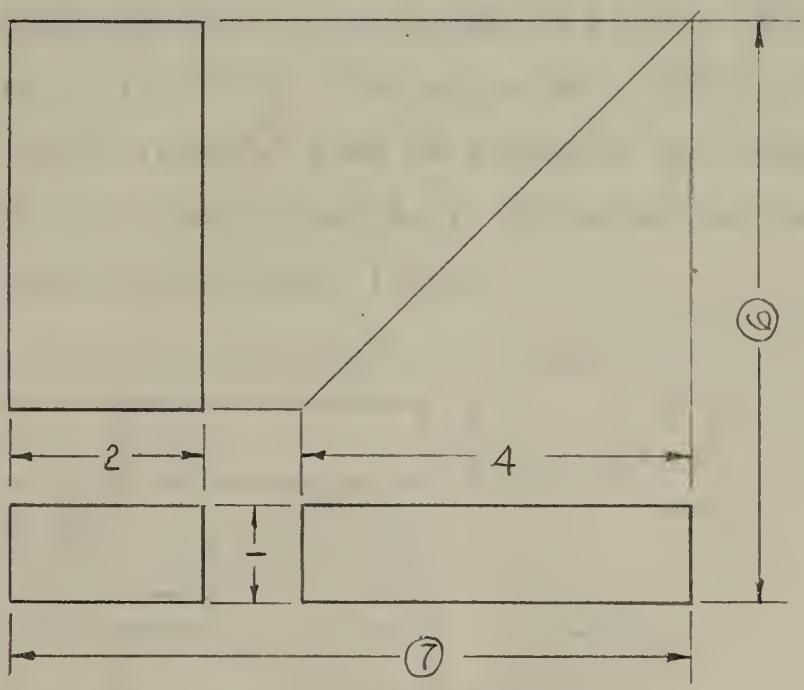


Figure 81 - The front view as the smallest view.

In Figure 81, the front view is the smallest view. Allowing 1" between views, the three-view drawing would occupy a space 6" by 7" on the paper. (0-90)

Dimensioning

Dimensions considered as directions for the workman.-- Under the heading of Orthographic Projection, shape descriptions of objects was studied. To study size descriptions, the topic to be considered is dimensioning. Dimensions give directions to the workman. They must be accurate and complete. The size of every detail in an object must be given. The surfaces to be finished must be indicated on the drawing. The material and number required have got to be stated. The scale to which the object was drawn must be shown. See Figure 82. Any feature of the drawing which cannot be clearly illustrated must be explained in a note. Thus, if inch marks are left off the drawing, a note stating, "All dimensions are in inches," must be placed on the drawing. See Figure 82. All these items serve as directions for the workman in making the object. (0-92)

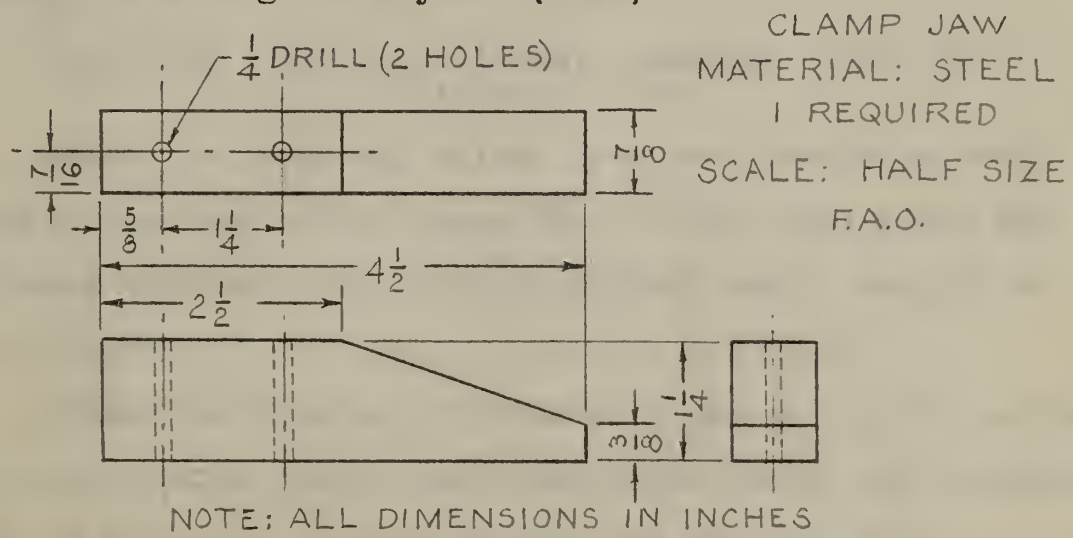


Figure 82 - A complete working drawing.

Dimensioning itemized.-- Complete dimensioning includes dimension lines, extension lines, arrowheads, figures, leaders, center lines, notes and finish marks. These items are all included in the complete working drawing in Figure 82. Extension lines are fine solid lines and begin about 1/16" from the outline of an object and extend about 1/8" beyond the dimension line. See Figure 83.

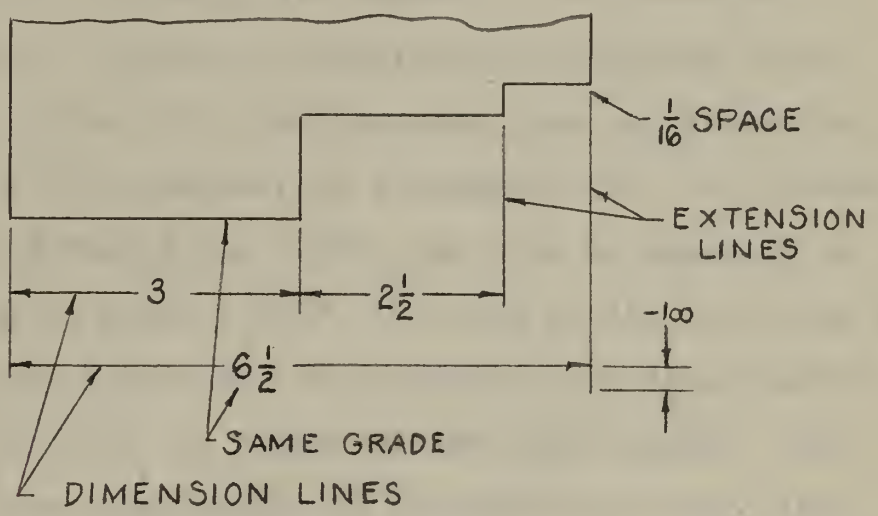


Figure 83 - Extension lines, dimension lines and figures.

Extension lines may extend from one view to another without touching either view. This is only done where the distance between views is comparatively small, say 1½" or less. (0-92)

Dimension lines are fine solid lines ending with arrowheads and making contact with extension lines. The dimension line is broken to allow space for the numeral. See Figure 83. (0-93)

Numerals are of the plain Gothic type and should be drawn the same grade as the outline of a view. See Figure 83.

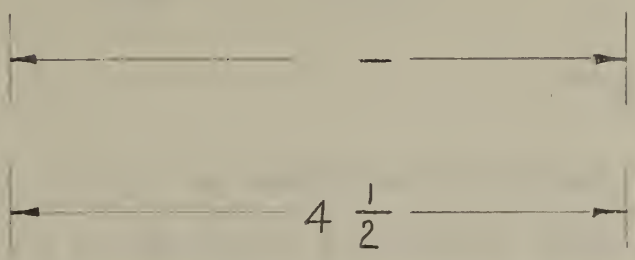


Figure 84 - Drawing the numeral in a dimension.

If the numeral contains a fraction, the fraction line should be in line with the dimension line and should be drawn before the numerator or denominator of the fraction is drawn. See Figure 84. (0-94) The size of numerals in dimensioning is usually 1/8", the same as the lettering on a drawing. See Figure 82. The numerator and denominator of a fraction are 2/3 the height of the whole number. See Figure 85. The total height of the fraction is 5/3 the height of the single number. For example, in Figure 85 the fraction "½" takes up 5/3 as much space as the whole number "2". (0-95)

$2\frac{1}{2}$

Figure 85 - Example of a numeral and fraction.

Arrowheads are the same grade as figures and are about 1/8" long. For large drawings, arrowheads are made slightly longer than 1/8". An attractive locking arrowhead is sharp, narrow, and filled-in as shown in Figure 86. The length of

the arrowhead is about three times the thickness. (0-96)

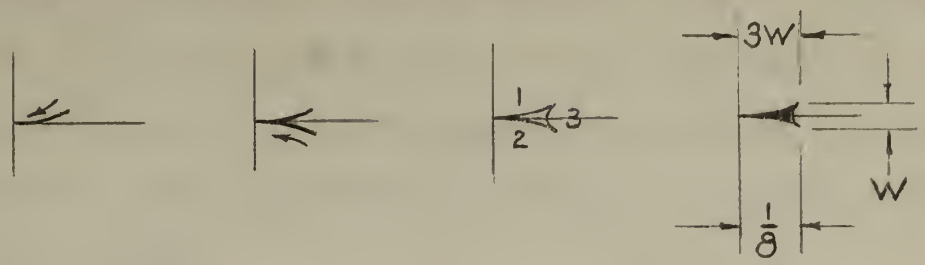


Figure 86 - Steps in making an arrowhead.

A leader is a fine solid line which leads from a note or dimension and ends with an arrowhead, the arrowhead touching the part to which attention is directed. See Figure 87. The word "Drill" following the dimensioning of a hole refers to diameter.

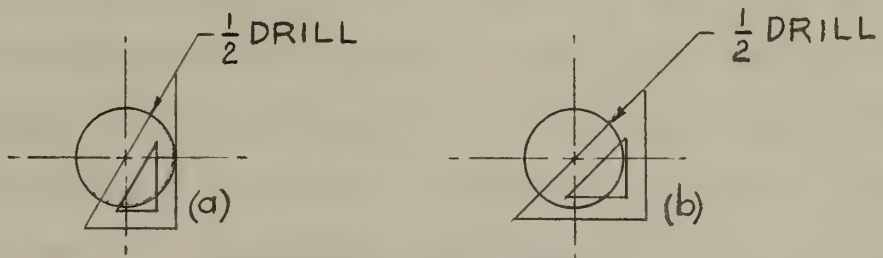


Figure 87 - Leaders

A leader should point to the center of a hole as shown in Figure 87, (a) and (b), and may be drawn either 45° or 60° to the horizontal. (0-97)

Giesecke, Mitchel and Spencer[1/] define a finish mark as follows: "A finish mark is used to show that a surface is to be machined or finished instead of being left rough, as on castings or forgings." Figure 88, (a), shows the old type finish mark. It is still being used in some drafting offices. The new type finish mark, Figure 88, (b), is the 60°/, the

1/ op. cit. p. 290.

new American Standard form. The point of the "V" touches the line representing the surface to be finished. The size of the "V" is given in the figure. If an object is to be finished all over a note such as "F.A.O." is used. See Figure 82. (0-98)

Figure 88 - Finish marks

Placing of dimensions on a drawing.-- Dimensioning is usually done in a horizontal or vertical position, with the figures reading from the bottom or the right-hand side of the drawing. Dimensions generally should be placed between views. The smaller or detail dimensions are nearer the view than the overall dimensions. The overall dimensions should be farthest away. When several dimension lines are used, they are parallel and are $\frac{1}{4}$" or 3/8" apart and $\frac{1}{4}$" or 3/8" away from the view. (0-99)

Inches are indicated by the symbol (") and are placed slightly above and to the right of the numeral. Feet are indicated by the symbol ('). Dimensions under two feet are given in inches, but if the dimension is two feet or over, it is given in feet and inches. For example, 18", but 2'-0" or 2'-6". When all dimensions are in inches, the inch marks (") are omitted and a note stating that all dimensions are in inches is placed on the drawing. (0-100)

Dimensions may be divided into three types; (a) detail, (b) position, and (c) overall. See Figure 89. (O-101)

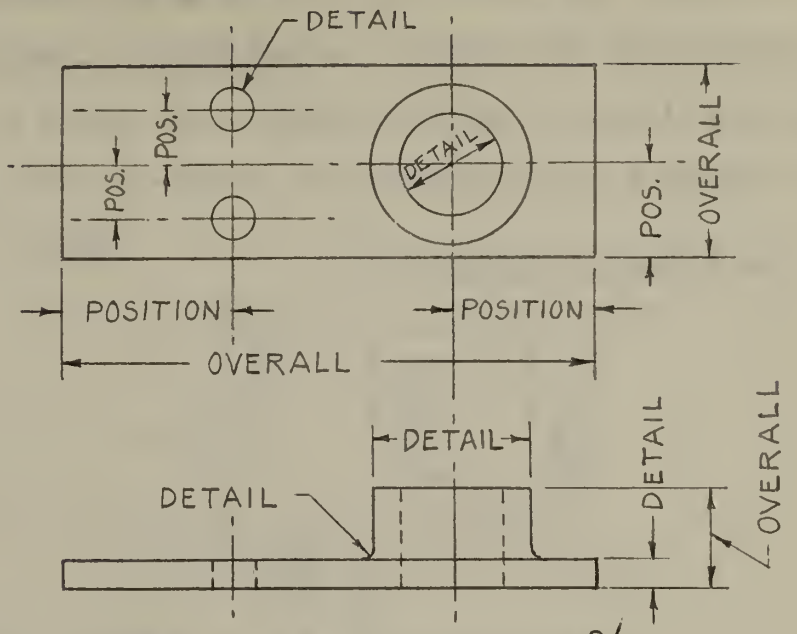


Figure 89 - Types of dimensions[a/]

Dimensioning a square hole.-- Figure 90 shows method of dimensioning a square hole. The types of dimensions, i.e; detail or size, position, and overall are indicated. The

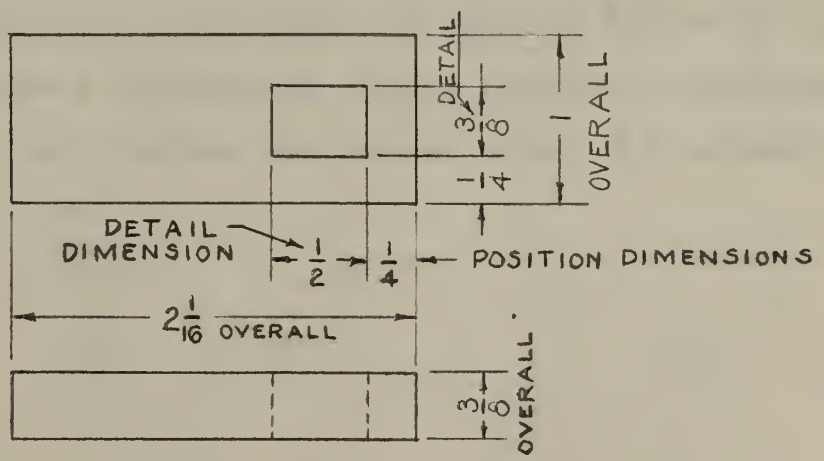


Figure 90 - Dimensioning a square hole.

a/ Adapted from Giesecke, Mitchel and Spencer, Technical Drawing. p. 291.

position dimensions extend from the edges of the view to the edges of the hole. (0-102)

Dimensioning a round hole.-- Figure 92 shows method of dimensioning a round hole. The locating or position dimensions extend from the edges of the view to the center lines of the hole. (0-103

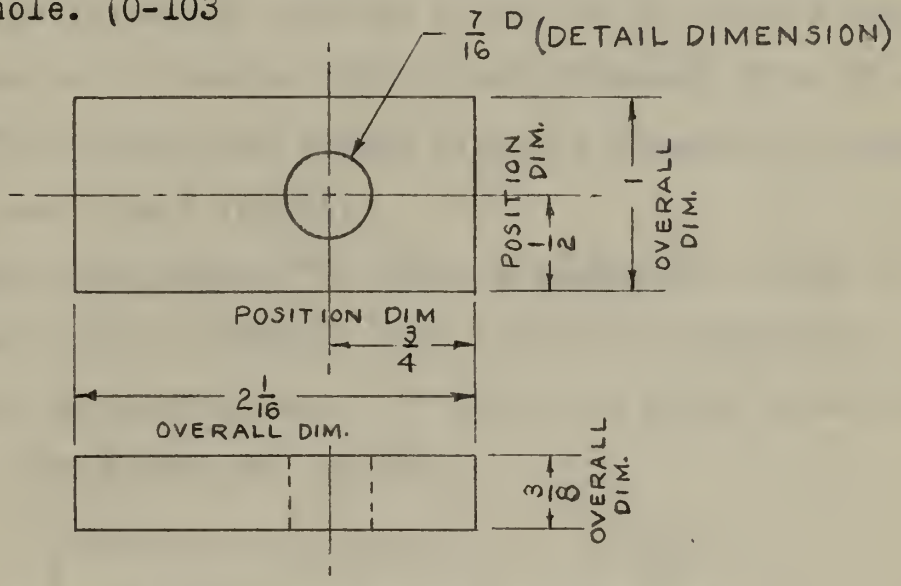


Figure 91 - Dimensioning a round hole.

Dimensioning cylindrical objects.-- Figure 92 (a) and (b) shows how a cylindrical object should be dimensioned. The length and diameter are placed about the rectangular

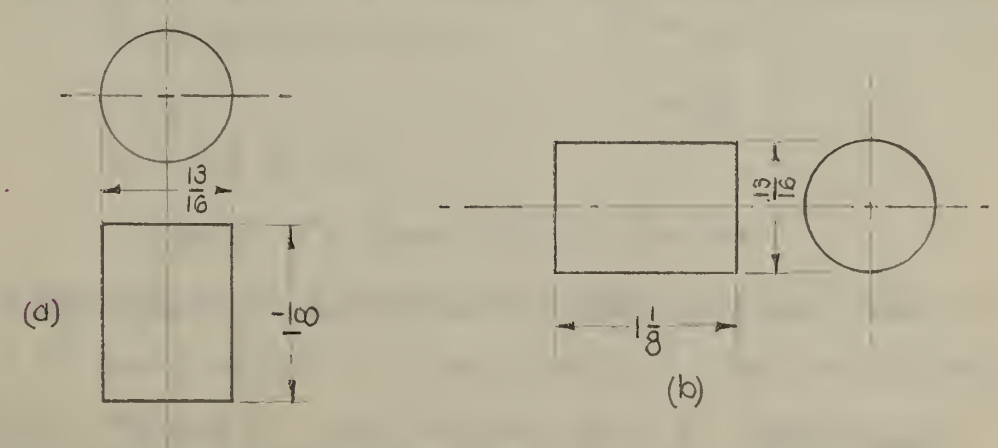


Figure 92 - Dimensioning the drawing of a cylinder.

view. The letter "D" signifying diameter need not be placed after .13/16" dimension because it is obvious from the circular view that the object must be round. However, this latter rule is rapidly becoming academic (a rule for classroom use only) because most drafting offices today require use of the letter "D" whether or not it is obvious that the dimension is a diameter. French and Svenson[1/] give this rule: "For cylindrical pieces give the diameter and length on the same view." (O-104)

Use of the letter "D" after a dimension.-- When it is not clear from the drawing that a dimension applies to a diameter, the abbreviation "D" should be given after the numeral. See Figure 93. (O-105)

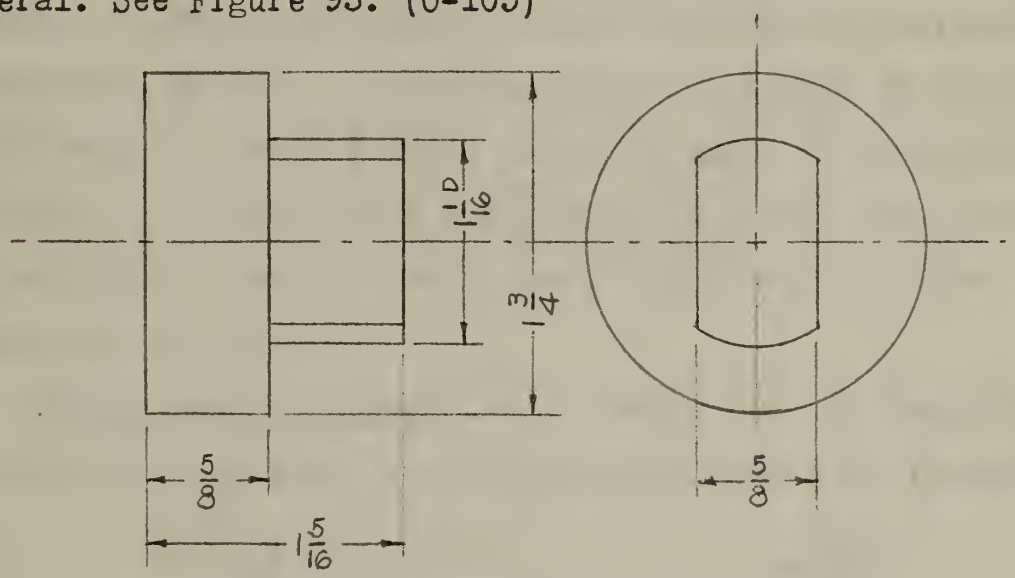


Figure 93 - Dimensioning circles.

Dimensioning of features with semi-circular ends.-- Figure 94 shows method of dimensioning a view having semi-

1/ French, Thomas E., and Svenson, Carl L., Mechanical Drawing for High Schools, McGraw-Hill Book Company, Inc., New York, 1943, p. 50.

circular ends. The "R" after ½" stands for radius. The overall dimension is omitted. In laying out such an object, the two centers would first be located and the semi-circular arcs would be drawn from these centers. (0-106)

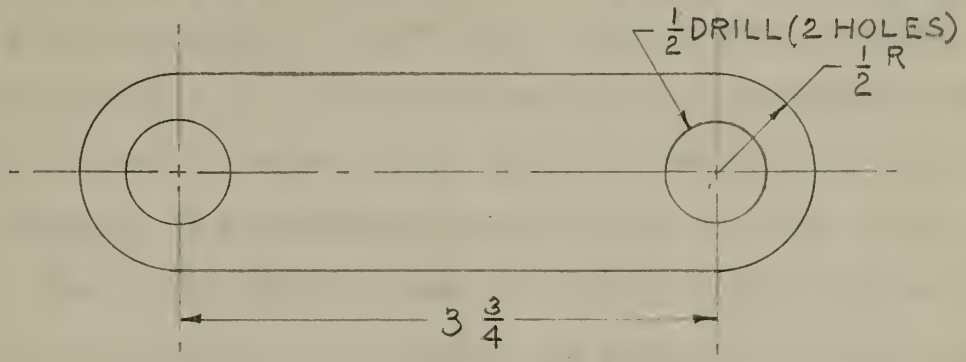


Figure 94 - Dimensioning features having semi-circular ends.

Dimensioning as efficient size description of an object.-- A well-dimensioned object will have a minimum of dimensions, without any duplications. In Figure 94 the note, (2 holes), following ½ Drill saves the need for using two leaders, i.e; one to each hole. Also, only one end of the semi-circular view is dimensioned, since both ends are identical. (0-107)

Dimensioning a chamfer.-- A chamfer may be dimensioned in two different ways. See Figure 95 (a) and (b). (0-108)

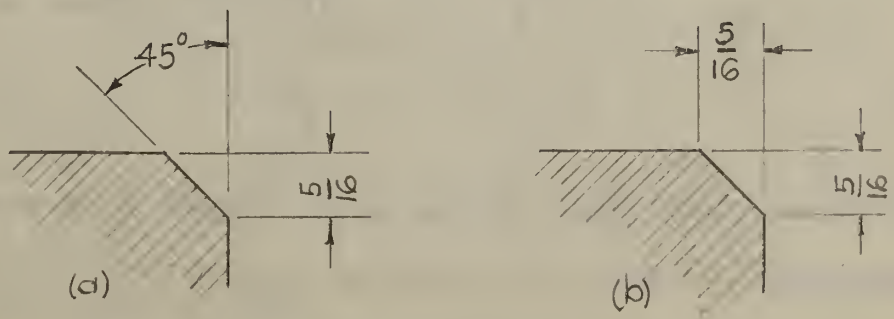


Figure 95 - Dimensioning a chamfer.

Dimensioning arcs of circles.-- Figure 96 shows method of dimensioning arcs of various sizes. In sketch (d) of Figure 96, the arc is so small that both the arrowhead and the numeral are placed outside the arc. In sketch (c), the arc is large enough to allow only the arrowhead inside. In sketch (a) and (b), both the numerals and arrowheads are placed inside the arcs, since there is room to do this without crowding. The arrowhead should touch the arc in all cases. The letter "R" is used to signify radius and must be used for all radii. It is drawn the same size as the numerator of a fraction. (0-109)

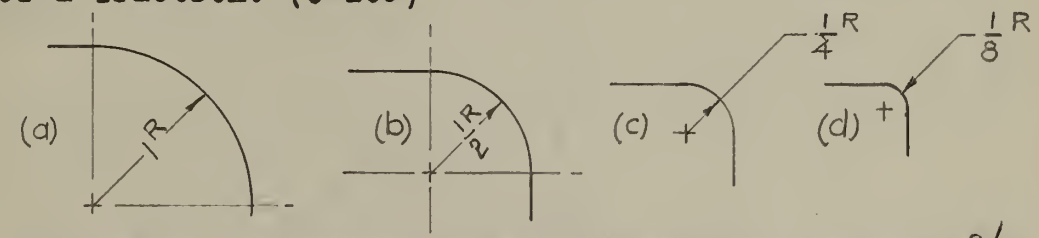


Figure 96 - Dimensioning arcs (American Standard)[a/]

Dimensioning angles.-- Figure 97 shows method of dimensioning angles of various sizes. If the angle is small as in sketch (b) of Figure 97, the 15° and the arrowheads are placed outside the angle. The arcs which are the dimension lines are drawn as fine solid lines using the vertix of the angle as a center. (0-110)

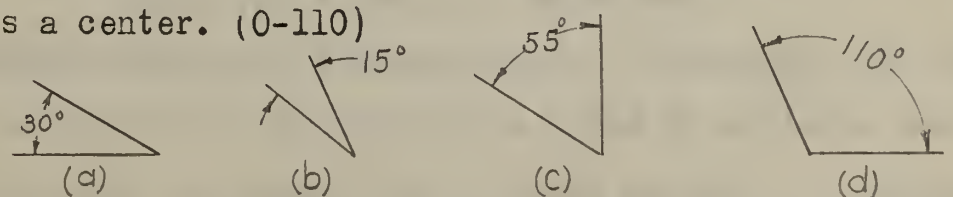


Figure 97 - Dimensioning angles (American Standard)[b/]

a/ Adapted from Giesecke, Mitchell and Spencer, Technical Drawing, Op. cit. p. 299

b/ Ibid.

Relation of figure to radial dimension line.-- In placing radial dimensions on a drawing, it is well to keep in mind the rule for placing dimensions on a drawing as given in (0-99), page 66. Figures should read from the bottom or right side of a view. In Figure 98, the radial dimensions are placed so that they are more easily read from a horizontal or right side position. The direction from which numerals are read changes at the vertical center line. The shaded area should be avoided because radial dimensions would be difficult to read in this position. (0-111)

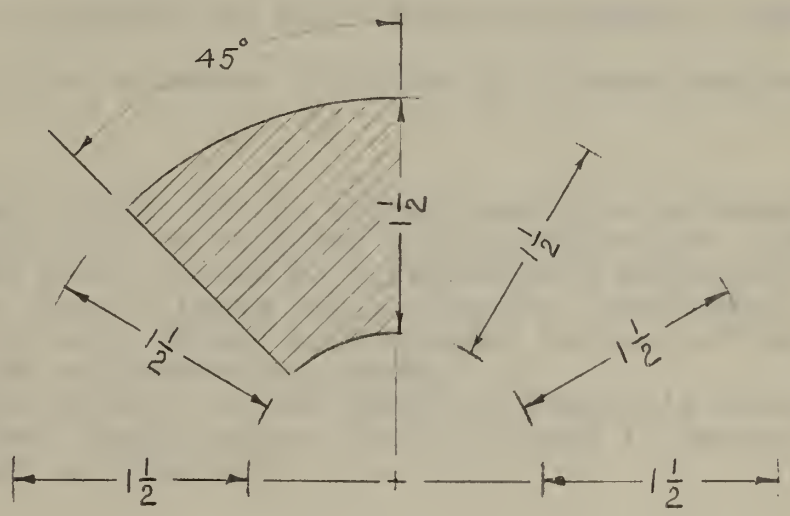


Figure 98 - Radial dimensions.[a/]

Dimensioning in a limited space.-- Figure 99 (a), shows method employed for dimensioning a space $\frac{1}{4}$" or less. Both the arrowheads and numerals are placed outside the extension lines.

a/ Adapted from a printed sheet entitled "Dimensioning" and produced by the Mechanical Drawing Association of New England. - Tentative Standards 1939-2.

In sketch (b) only the arrowheads are placed outside, while the numeral goes inside. In sketch (c), both the arrowheads and figures are placed inside the extension lines since the dimension is over ½" in length. (0-112)

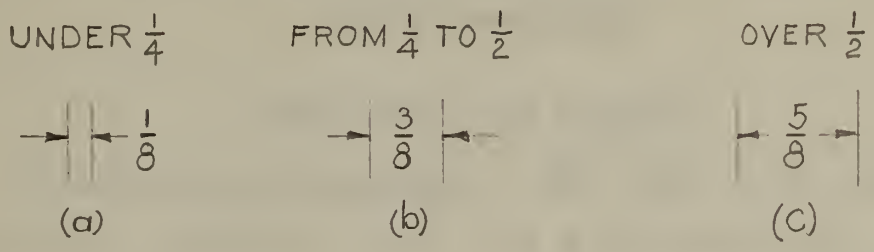


Figure 99 - Dimensioning in a limited space.[a/]

Some general rules in dimensioning.-- William W. Klenke and Charles J. Hayes[1/] in their text on Elementary Mechanical Drawing, list a number of rules for dimensions among which are:

> The outline of the object should be outstanding and should not be confused with construction lines.
> The views should be arranged with sufficient space between them to leave ample room for dimensions.
> All views should be completed before putting on extension and dimension lines.
> Dimensioning dotted edges of invisible parts of the object should be avoided, although it becomes necessary on occasion.

a/ Op. cit. 1939-2

1/ Op. cit. pp. 111, 113, 115

CHAPTER III

HIGH-SCHOOL MECHANICAL-DRAWING TEST: GRADE X--MIDYEAR

Description and Purpose

Description of the test.-- The test is in six parts and is entirely objective. Part I is a true and false test of 58 items. These items are grouped under four major headings which are: (1) Instruments and Materials, (2) Geometric Problems, (3) Orthographic Projection, and (4) Dimensioning. Part II is a matching test of 15 items on the subject of geometry for mechanical drawing. Part III is a test of 5 items in geometric construction by use of compasses and straight edge. This is a test for skill as well as understanding. To be objective, each item must be completely correct. No credit is given for items partly right. Part IV of 4 items is a multiple-choice test on computing the margins for centering a three-view orthographic drawing. Part V is a completion test of 6 items in orthographic projection. Like Part III, it is a test in skill as well as understanding for the student must use the drawing board, T-square and triangle to supply the missing views. Part VI, A, B, and C are blueprint reading tests of 35 items which vary in degree of difficulty.

The test has been designed to measure pupils' knowledge and understanding of mechanical drawing, but at the same time to measure the pupils' skill in handling instruments, and their ability to read drawings. It is an achievement test.

The purpose of the test.-- The test may be used to:-

1. Find out how much the pupils know in order that the instructor may know what to teach next. After giving this midyear test an instructor may discover that some or all pupils are not ready to go on with the more advanced work. The test would show just what phases of the first half years work needed review.

2. Determine what pupils need remedial work. Since the test items are grouped under distinct units of mechanical drawing it would be an easy matter to discover in just what phases of drawing a student is weak. By the use of the student record sheet for the tabulation of numerical scores weaknesses can be easily spotted. The student record sheets for all classes in Grade X would be the sources from which a special class could be made up. Individuals showing decided weaknesses in a majority of the units could be selected for this class which would receive special instruction.

3. Check the instructor. If a large number of pupils failed the test it might be an indication that the instructor fell down on the job. Even the best of instructors may at times slide over objectives rather hurriedly in order to

meet the requirements of the course.

4. Determine pupils' marks. Since the test samples widely the field of elementary mechanical drawing, it can truely be said to be comprehensive. From the curricular standpoint the test is valid. I have checked all items in the very best of mechanical drawing text books. A valid and comprehensive test should be a very good measure for pupils' marks. Since the test is entirely objective, a more reliable basis for assignment of pupils' marks will be furnished than that afforded by the subjective tests of teachers.

5. Compare the results obtained by the teacher of one class with the accomplishments of similar classes in the same school or in other schools.

6. Motivate pupil effort. Pupils will try harder and put more into their work when they know that they are going to be thoroughly and scientifically tested.

The test has been designed principally for a local high school, namely Boston Technical High. However, since the teaching objectives as set forth in Chapter II of this thesis parallel the elementary mechanical drawing as set forth in the best of the modern text books, I feel that the test may be used in any high school.

The test items of Chapter III are matched to the teaching objectives of Chapter II. This is done by the use of the symbol (O) which stands for teaching objective. For

example, the test item one of Chapter III (page 81) is followed by the symbol (O-6). This means that this test item is testing the statements or teaching objectives set forth in Chapter II (page 8, paragraph one) for this paragraph is followed by the symbol (O-6)

The writer is grateful to Mr. Louis A. Van Ham, head of the Drafting department at Boston Technical High School. Mr. Van Ham did the original work in Part VI of this test and his criticism of many items in the test has been helpful. The writer is also grateful to Messrs. William MacRobbie, Charles Packard, William Powers, and Fred Nichols for taking part in the administration of this test.

The test has been administered to 450 high school students of grade X. The students have had one-half years work in mechanical drawing consisting of three -40 minute periods a week. From their scores norms have been determined. The median is 129.4. The mean calculated is 127.4. The standard deviation is 24.45. From these norms, the students' raw scores are converted into class marks. The following table is significant:-

A = Above 164
B = 140 to 164
C = 116 to 139
D = 90 to 115
E = Below 90

Pupil test scores revealed an outstanding weakness in com-

puting margins for an orthographic drawing. This weakness was traced to pupils' inability to handle simple fractions. The writer has not undertaken in this thesis to give further analysis of test results.

Directions for Administering

The time element as a very important item of validity.- If strict time limits are not adhered to, the test will be invalid. The time limits for each part of the test are as follows:

PART I	allow	20	minutes	+	2	
PART II	allow	8	minutes		2	
PART III	allow	20	minutes		2	
PART IV	A allow B allow	2½ 2½	minutes) minutes)		2	
PART V	allow	15	minutes		2	
PART VI	A allow B allow C allow	5 5 10	minutes) minutes) minutes)		2	
	TOTAL	73	minutes		12	= 85 minutes

The total students working time is 73 minutes. Allow 12 minutes for giving out papers and the reading of directions. The directions for the students are printed on each part of the test. Time limits were arrived at by trying out the test with students of average ability. Students should be told to keep their papers face down until all tests are given out.

Directions for Scoring

Ease in scoring as an important element in objective tests.-- Space is provided at the bottom of each test part for marking the score. These scores may be totaled on page 96 of this test. Since the test is wholly objective, anybody may score it. A key to all test parts is provided. With the student class record sheet, each pupil's results may be analyzed and remedial measures taken. A summary of the maximum scores follows:-

PART I	Number right			=	58
PART II	"	"		=	15
PART III	"	"	= 5 x 3	=	15
PART IV	(A "	"	= 2 x 2	=	4
	(B "	"	= 2 x 2	=	4
PART V	"	"	= 6 x 3	=	18
PART VI	(A "	"	= 10 x 2	=	20
	(B "	"	= 10 x 2	=	20
	(C "	"	= 15 x 2	=	30
			TOTAL SCORE	=	184
			TOTAL NUMBER OF ITEMS	=	50

CLASS RECORD SHEET										
NAME OF PUPIL	PART I	PART II	PART III	PART IV		PART V	PART VI			TOTAL
				A	B		A	B	C	

PART 1 - TRUE AND FALSE

DIRECTIONS:- Read the following sentences carefully. If a statement is true, draw a freehand circle about the "T". If a statement is false, circle the "F". For example, the first statement is true, so the "T" has been circled.

Instruments and Materials

(T) F 1. One of the triangles used in mechanical drawing has two 45° angles and one 90° angle. (0-6)

T F 2. The T-square and the 30°-60° triangle together are used for drawing vertical lines. (0-5)

T F 3. The bow compasses are used for drawing circles of 7/8" radius or less. (0-19)

T F 4. The 4-H pencil should be used for lining-in a drawing. (0-10)

T F 5. The normal position of the T-square should be with the head against the top edge of the drawing board. (0-4)

T F 6. The H pencil is preferable for drawing extension and dimension lines. (0-10)

T F 7. By means of the architect's scale the drawing of an object may be made full size, three-quarter size, half size, or one-eighth size. (0-13)

T F 8. The scale $1\frac{1}{2}$"=1" means that $1\frac{1}{2}$" on the drawing equals 1" on the object, or the drawing is $1\frac{1}{2}$ times the size of the object. (0-15)

T F 9. The dividers are used to transfer distances. (0-18)

T F 10. If a circle is to be made larger than 3" in radius, the legs of the compass should be bent so that they are perpendicular to the paper. (0-19)

T F 11. The bevel on a compass lead should be on the inside. (0-20)

T F 12. Drafting tape is more economical than thumb tacks for holding the paper to the drawing board. (0-22)

Score: 58 items
Score equals number right=_____

T F 13. In laying out the border lines of a drawing paper, the measuring should be done on one vertical and one horizontal line. (0-26) (0-27)

T F 14. In making a three-view orthographic drawing the views should first be "blocked-out". (0-29)

T F 15. A center line is a heavy line of alternate long and short dashes. (0-30)

Geometric Problems

T F 16. The radius of a circle is one-half its diameter. (0-38)

T F 17. A line that is tangent to a circle has two points in common with the circle. (0-73)

T F 18. A tangent to a circle makes a right angle with the radius drawn to that point. (0-73)

T F 19. The diameter of a circle is the shortest chord that may be drawn in the circle. (0-38)

T F 20. A perpendicular to a line forms an angle of 90° with the line. (0-66)

T F 21. An obtuse angle is an angle greater than 180°. (0-34)

T F 22. An acute angle is greater than 90° but less than 180°.

T F 23. The perimeter of a polygon is its outline or the lines which enclose it. (0-39)

T F 24. An equilateral polygon is a polygon that has all its angles equal. (0-40)

T F 25. A quadrilateral is a four-sided polygon. (0-43)

T F 26. The diagonal of a quadrilateral is a straight line joining two opposite vertices. (0-44)

T F 27. The angles of any triangle add up to 150°. (0-48)

T F 28. To bisect means to divide into two equal parts. (0-64)

T F 29. To construct a square, a perpendicular to a line must first be drawn. (0-70)

T F 30. To find the center from which an arc is drawn, bisecters of chords are employed. (0-64) (0-72)

T F 31. Any angle inscribed in a semi-circle is a 60° angle. (O-73)

T F 32. A regular hexagon has a long and short diameter. (O-52)

Orthographic Projection

T F 33. The vertical height of the top view of an object, as shown on drawing paper, is equal to the horizontal width of the side view. (O-78) (O-82)

T F 34. In orthographic projection the height of the front view of an object is equal to the height of the top view. (O-78) (O-82)

T F 35. If perpendiculars are extended from all points on the face of an object to a plane of projection, the picture so formed on the plane of projection is known as orthographic projection. (O-80)

T F 36. A perspective drawing shows an object as viewed from one point, the eye of the observer. (O-79)

T F 37. In orthographic projection, the length of the top view, in the drawing of an object equals the length of the side view. (O-78)

T F 38. In the orthographic projection of an oblique surface the projection lines are at right angles to the oblique surface. (O-84)

T F 39. Cylindrical objects may be fully represented in two views. (O-88)

T F 40. The principal view is that view which gives the most information concerning the characteristic form of the object. (O-89)

T F 41. The principal view is generally the front view of a three-view drawing.

Dimensioning

T F 42. Dimension lines are fine solid lines ending with arrowheads and stopping 1/16" from extension lines.

T F 43. The total height of a fractional dimension should equal the height of a single numeral. (O-95)

T F 44. The length of an arrowhead is approximately three times its thickness. (0-96)

T F 45. A leader to a circular hole should be drawn at an angle of 60° or 45° with the horizontal. (0-97)

T F 46. Dimensioning is usually done in a horizontal or vertical position, with the figures reading from the bottom or the right-hand side of the drawing. (0-99)

T F 47. A circular hole should be located by dimensioning to its edge. (0-103)

T F 48. In the dimensioning of a cylindrical object, both the diameter and length should be placed about the rectangular view. (0-104)

T F 49. A working drawing must be fully dimensioned.(0-82, 91)

T F 50. The radius should be given as the dimension for the size of a round hole. (0-106)(0-109)

T F 51. Extension lines should touch the outline of a view. (0-92)

T F 52. A dimension line should be no nearer to a view than 1/8 of an inch. (0-99)

T F 53. According to the American Standards Association, the figure denoting the size of an angle may be placed in a horizontal position, for angles of 90° or less. (0-110)

T F 54. The word "Drill" following the dimensioning of a circular hole refers to radius. (0-97)

T F 55. Dimension lines are generally equally spaced between views. (0-99)

T F 56. Dimensions can be considered as directions for the workman. (0-91)

T F 57. Numerals in dimensioning should be the same grade as extension lines. (0-94)

T F 58. In dimensioning an arc of 1/8" radius, the arrowhead should be placed outside the arc, but touching it.(0-109

T F 59. For dimensions under $\frac{1}{4}$", the arrowheads and figures should be placed outside the extension lines. (0-112)

PART II - THE GEOMETRY FOR MECHANICAL DRAWING.

DIRECTIONS: There are 16 true statements, lettered from a to q. At the left of these statements are 23 terms. From these pick out the term which best matches a statement and place its number in front of the statement. For example, the term which best matches statement a is A regular polygon; therefore, the number of the term (number 12) has been placed in front of statement a.

1. A regular octagon
2. A triangle
3. A perpendicular
4. Vertex
5. A regular hexagon
6. Parallelogram
7. A pentagon
8. Quadralateral
9. An ellipse
10. A polygon
11. An isosceles triangle
12. A regular polygon
13. Equi-angular polygon
14. A rectangle
15. A square
16. Parallel
17. A trapezoid
18. Diagonal
19. Hypotenuse
20. A tangent
21. Segment
22. An equilateral triangle
23. Perimeter

12 a. A general term for enclosed plane figures that are both equilateral and equiangular. (0-39)

__ b. A name for all four-sided figures. (0-42)

__ c. An enclosed figure of eight equal sides and angles. (0-61)

__ d. A quadralateral that is both equilateral and equiangular. (0-43, 70)

__ e. A line outside a circle, joining the circle at but one point and forming a 90° angle with the radius drawn to the point of contact. (0-73)

__ f. A polygon of three sides. (0-41)

__ g. A figure inscribed in a circle by using the radius of that circle spaced six times on the circumference. (0-49, 53)

__ h. A line 90° to a given line. (0-66)

__ j. Two lines which would not meet, however far extended. (0-71)

__ k. The outline of a polygon. (0-39)

__ l. The part of an angle where the two sides meet. (0-31)

__ m. An enclosed plane figure bounded by three or more straight lines. (0-39)

__ n. A polygon of three equal sides. (0-41)

__ o. A polygon having all angles equal. (0-40)

__ p. A quadrilateral having its opposite sides parallel. (0-44)

__ q. A parallelogram having its angles right angles. (0-44)

Score:

15 Items

Number right=____

PART III - GEOMETRIC PROBLEM TEST [1]

DIRECTIONS: Complete the problems by use of compass and straight edge. Leave all construction lines on paper.

1. With line AB as a side, construct a hexagon. (C-49, 50, 52)

2. Using AB as a long diameter, construct a hexagon. (C-53, 55)

A ——————— B

A ——————— B

3. Construct a square on the base CD. (C-67, 68, 70)

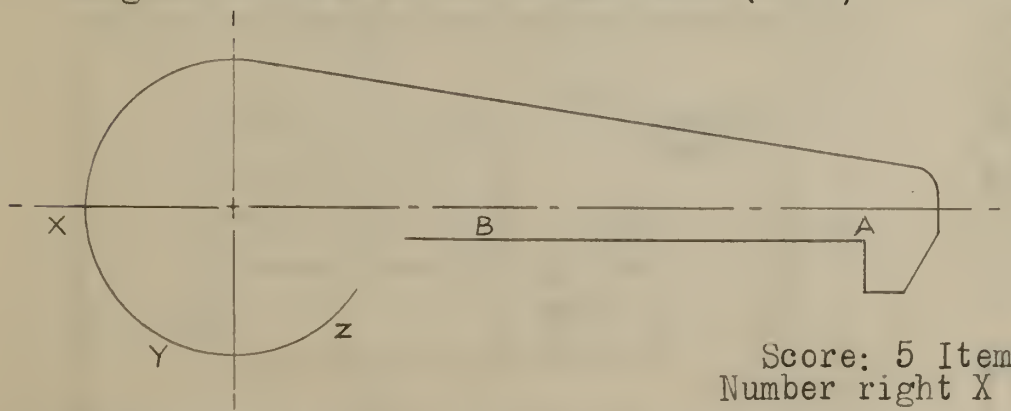
4. Construct a tangent to the circle C from an outside point P. (C-73)

C ——————— D

P

C

5. On the drawing of the pawl, construct a $\frac{3}{4}$" radius fillet tangent to line AB and to arc XYZ. (C-75)



Score: 5 Items
Number right X 3=____

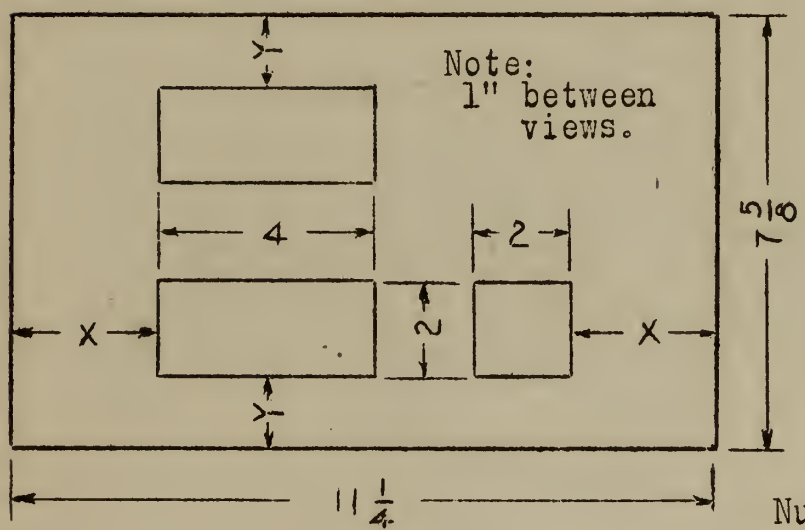
1/ Achievement Test in Mechanical Drawing, Harry M. Wright, Public School Publishing Company, Bloomington, Illinois, Part V, p. 9.

PART IV - COMPUTING MARGINS FOR A THREE-VIEW ORTHOGRAPHIC DRAWING

DIRECTIONS: Assuming the three views are placed in the middle of a rectangle which measures 7 5/8 by 11¼, figure the X margins and Y margins. The correct answers are in the answer column. Circle the figures that agree with your answers. Note that 1" is to be left between views. Do your figuring on the margins of this paper or on a scrap piece of paper.

(0-28)(0-29) (0-77) (0-78) (0-80) (0-81) (0-82)

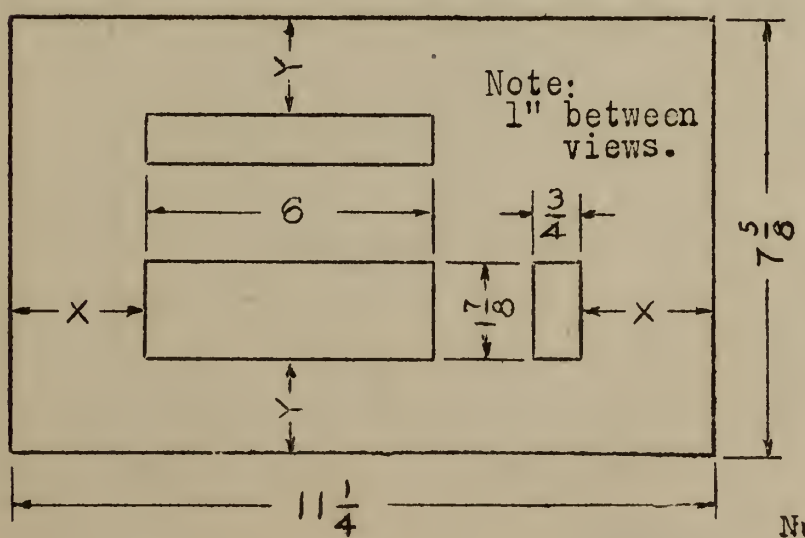
PROBLEM A



ANSWER COLUMN	
X	Y
$2\frac{5}{8}$	$1\frac{7}{8}$
$2\frac{1}{4}$	$1\frac{7}{16}$
$2\frac{1}{8}$	$1\frac{5}{16}$
$2\frac{3}{4}$	$1\frac{13}{16}$

Score: 2 Items
Number right X 2= ___

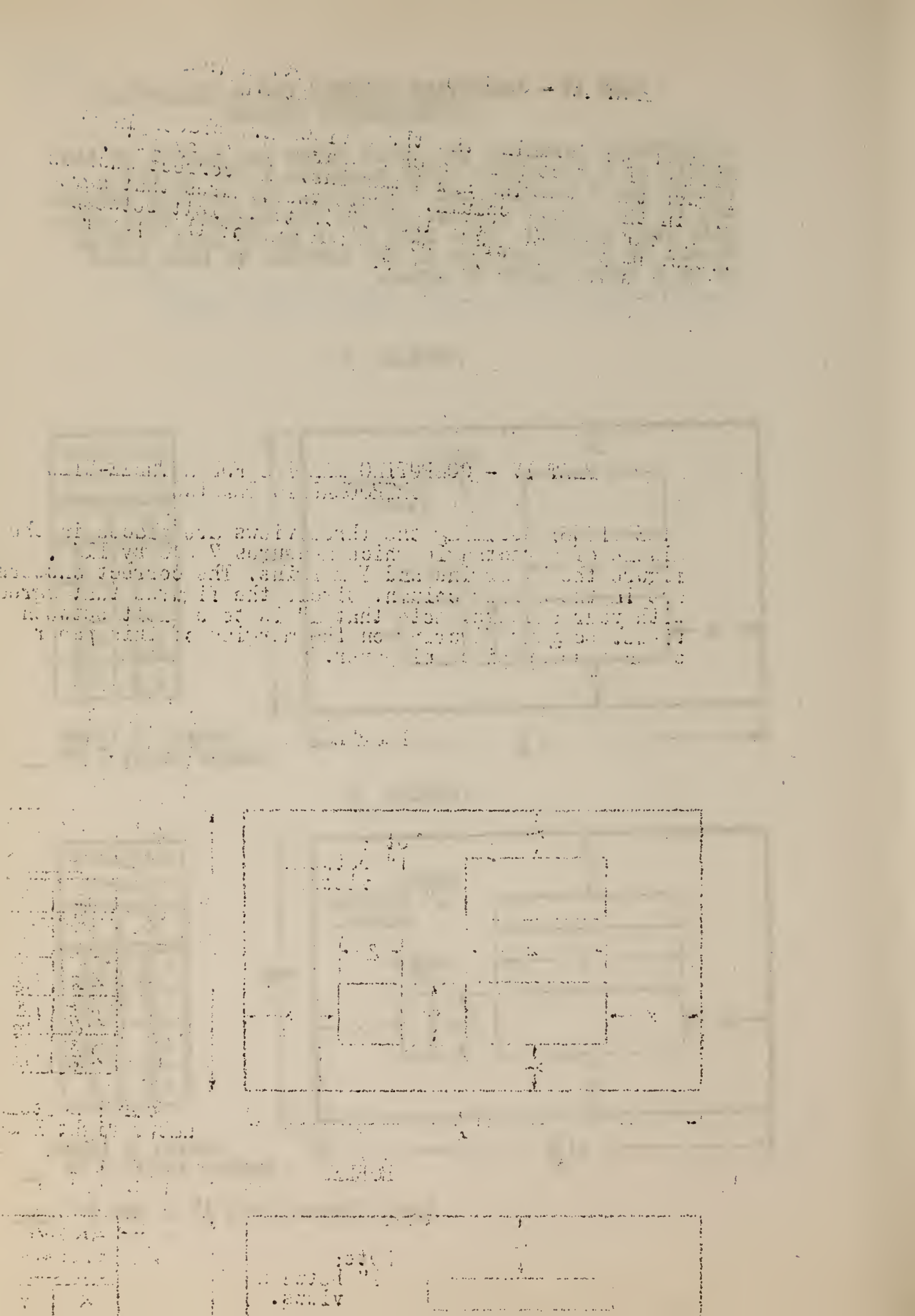
PROBLEM B



ANSWER COLUMN	
X	Y
$1\frac{13}{16}$	$2\frac{1}{16}$
$1\frac{3}{4}$	$1\frac{15}{16}$
$1\frac{5}{8}$	$2\frac{3}{16}$
$1\frac{1}{8}$	2

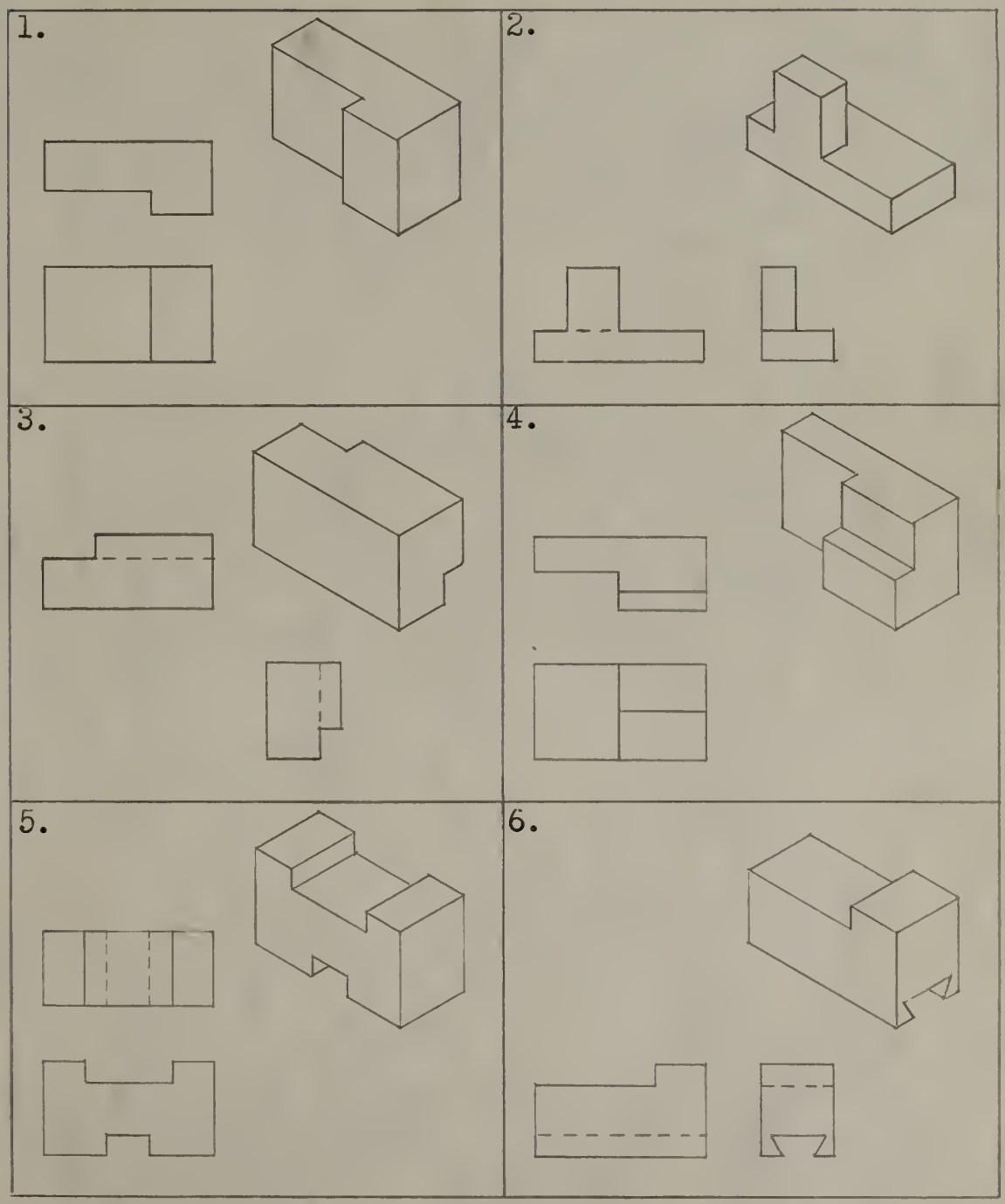
Score: 2 Items
Number right Y 2= ___

Total Score, Part IV A and B = ___



PART V - ORTHOGRAPHIC PROJECTION TEST

DIRECTIONS: Draw the missing view in each of the six problems. (0-77, 78, 80, 81, 82)

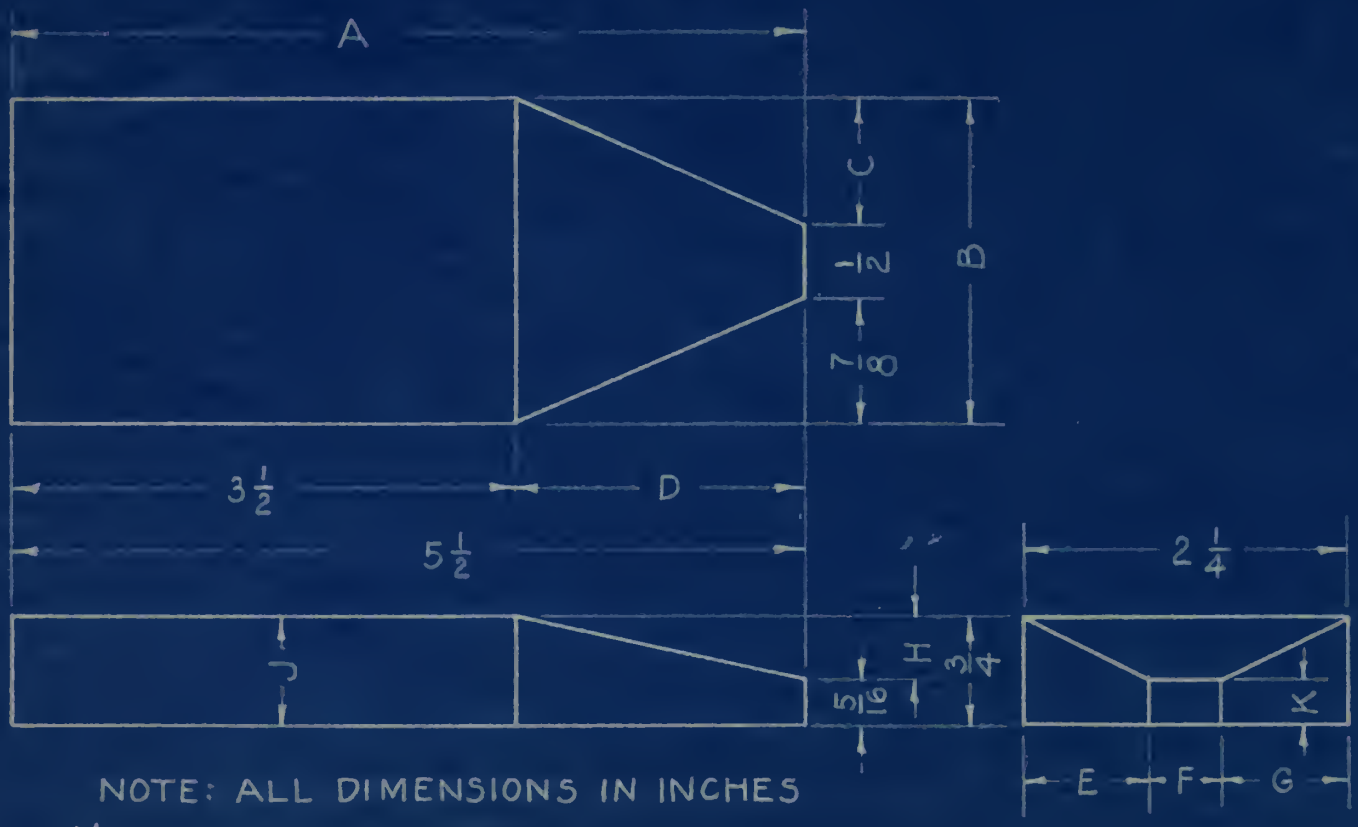


Score: 6 items
Number right X 3= ____

PART VI-A BLUEPRINT READING TEST

DIRECTIONS: READ THE THREE-VIEW DRAWING AND PLACE VALUE OF EACH LETTER IN ANSWER COLUMN. [1]

PLANER PINCH DOWN
MATERIAL: STEEL
SCALE: $\frac{3}{4}$" = 1"



ANSWER COLUMN	
A	
B	
C	
D	
E	
F	
G	
H	
J	
K	

NOTE: ALL DIMENSIONS IN INCHES

SCORE:
10 ITEMS
NUMBER RIGHT X 2 = ____

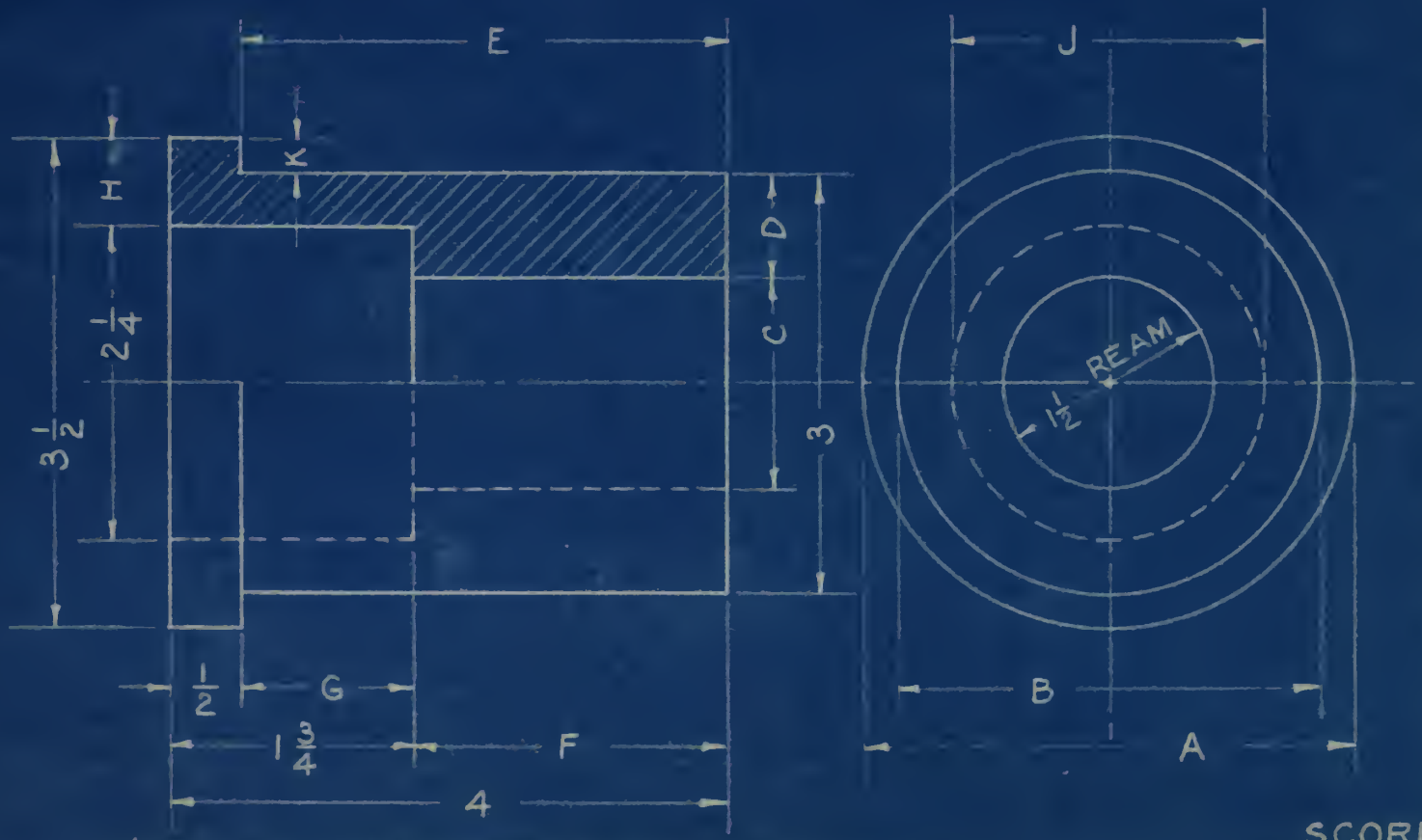
[1] (0-77-85, 88-101)

PART VI-B BLUEPRINT READING TEST

DIRECTIONS: READ THE TWO-VIEW DRAWING AND PLACE THE VALUE OF EACH LETTER IN ANSWER COLUMN. 1/

BUSHING
MATERIAL: CAST IRON
SCALE: $\frac{3}{4}$" = 1" F.A.O.

NOTE:
ALL DIMENSIONS IN INCHES



ANSWER COLUMN	
A	
B.	
C	
D	
E	
F	
G	
H	
J	
K	

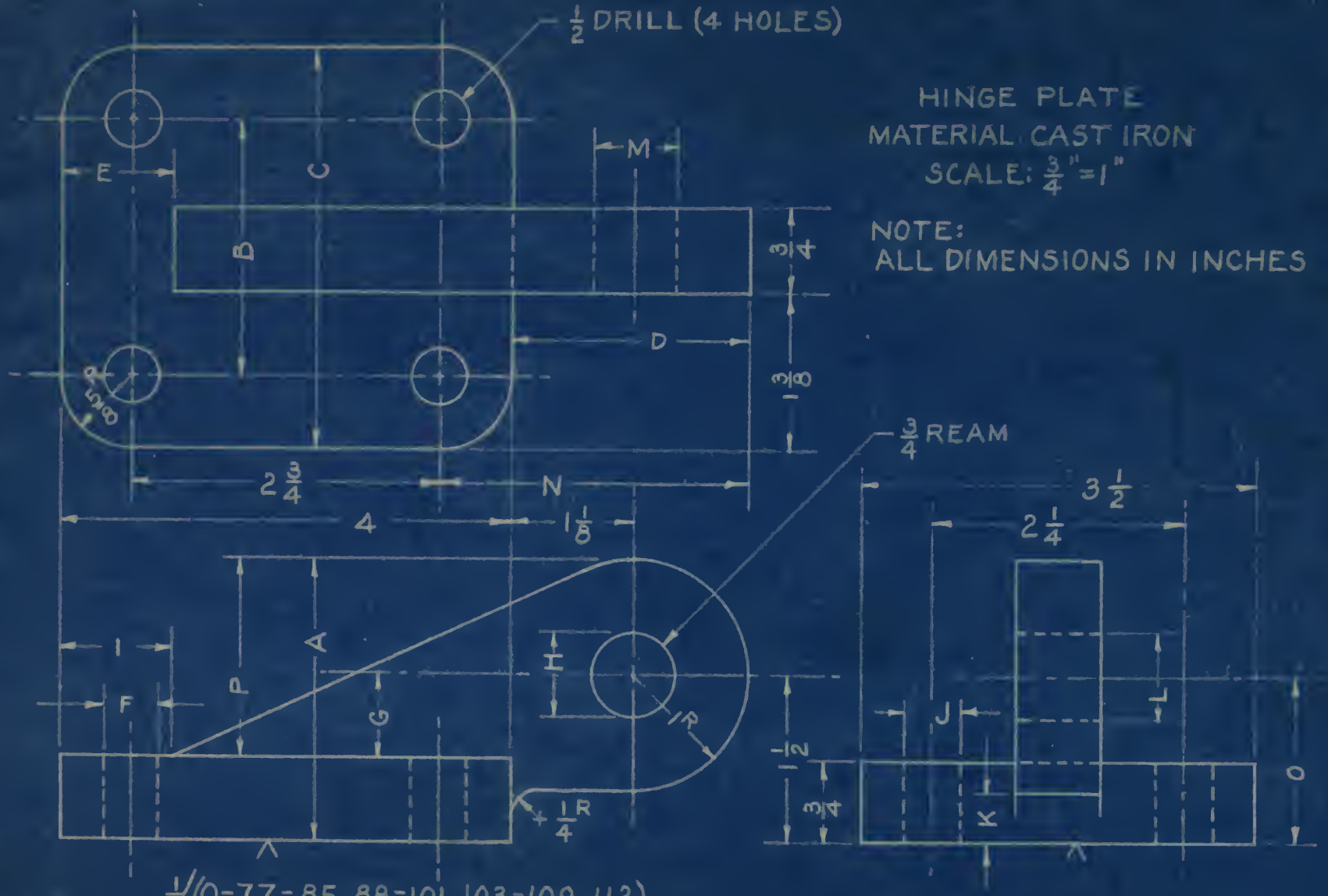
1/(0-77-85, 88-101, 103-109, 112)

SCORE: 10 ITEMS
NUMER RIGHT X 2 = ___

PART VI-C BLUEPRINT READING TEST[2/]

2/ Suggested by Charles Quinlan, Jr., "Try This One" Industrial Arts and Vocational Magazine, Tracing Supplement No. 283, February 1934.

DIRECTIONS: READ THE THREE-VIEW DRAWING AND PLACE VALUE OF EACH LETTER IN ANSWER COLUMNS.[1]



HINGE PLATE
MATERIAL CAST IRON
SCALE: ¾" = 1"

NOTE:
ALL DIMENSIONS IN INCHES

[1] (0-77-85, 88-101, 103-109, 112)

PART VI-C BLUEPRINT READING TEST

ANSWER COLUMN	
A	
B	
C	
D	
E	
F	
G	
H	

ANSWER COLUMN	
J	
K	
L	
M	
N	
O	
P	

SCORE: 15 ITEMS
NUMBER RIGHT X 2 = ____

KEY
PART I

2	T	
3	T	
4		F
5		F
6		F
7	T	
8	T	
9	T	
10	T	
11		F
12	T	
13	T	
14	T	
15		F
16	T	
17		F
18	T	
19		F
20	T	
21		F
22		F
23	T	
24		F
25	T	
26	T	
27		F
28	T	
29	T	
30	T	
31		F
32	T	
33	T	
34		F
35	T	
36	T	
37		F
38		F
39	T	
40	T	
41	T	
42		F
43		F
44	T	
45	T	
46	T	
47		F
48	T	
49	T	
50		F
51		F
52		F
53	T	
54		F
55	T	
56	T	
57		F
58	T	
59	T	

Note: This key is laid out so that each item in it will be exactly opposite the corresponding item in the test, when the two papers are matched.

KEY

PART II, IV-A & B, VI-A, B & C.

PART VI-A

ANSWER COLUMN	
A	$5\frac{1}{2}$
B	$2\frac{1}{4}$
C	$\frac{7}{8}$
D	2
E	$\frac{7}{8}$
F	$\frac{1}{2}$
G	$\frac{7}{8}$
H	$\frac{7}{16}$
J	$\frac{3}{4}$
K	$\frac{5}{16}$

PART VI-B

ANSWER COLUMN	
A	$3\frac{1}{2}$
B	3
C	$1\frac{1}{2}$
D	$\frac{3}{4}$
E	$3\frac{1}{2}$
F	$2\frac{1}{4}$
G	$1\frac{1}{4}$
H	$\frac{5}{8}$
J	$2\frac{1}{4}$
K	$\frac{1}{4}$

PART VI-C

ANSWER COLUMN	
A	$2\frac{1}{2}$
B	$2\frac{1}{4}$
C	$3\frac{1}{2}$
D	$2\frac{1}{8}$
E	1
F	$\frac{1}{2}$
G	$\frac{3}{4}$
H	$\frac{3}{4}$
J	$\frac{1}{2}$
K	$\frac{1}{2}$
L	$\frac{3}{4}$
M	$\frac{3}{4}$
N	$2\frac{3}{4}$
O	$1\frac{1}{2}$
P	$1\frac{3}{4}$

PART II

12	a
8	b
1	c
15	d
20	e
2	f
5	g
3	h
16	j
23	k
4	l
10	m
22	n
13	o
6	p
14	q

PART IV-A

ANSWER COLUMN	
X	Y
$2\frac{1}{8}$	$1\frac{5}{16}$

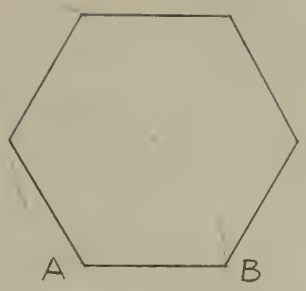
PART IV-B

ANSWER COLUMN	
X	Y
$1\frac{3}{4}$	
	2

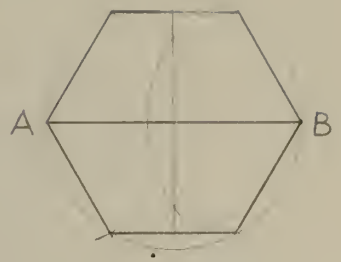
KEY

PART III

1.



2.



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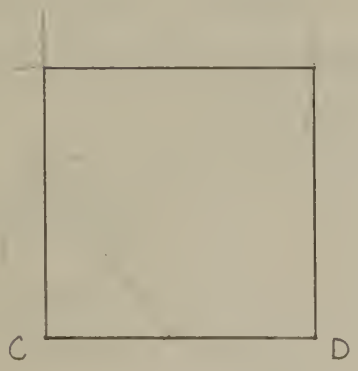

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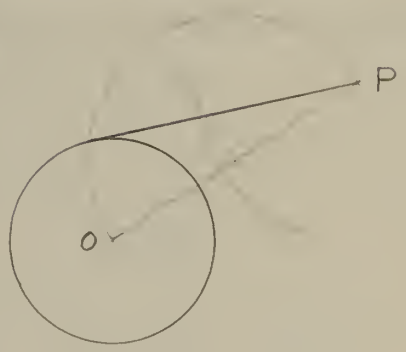

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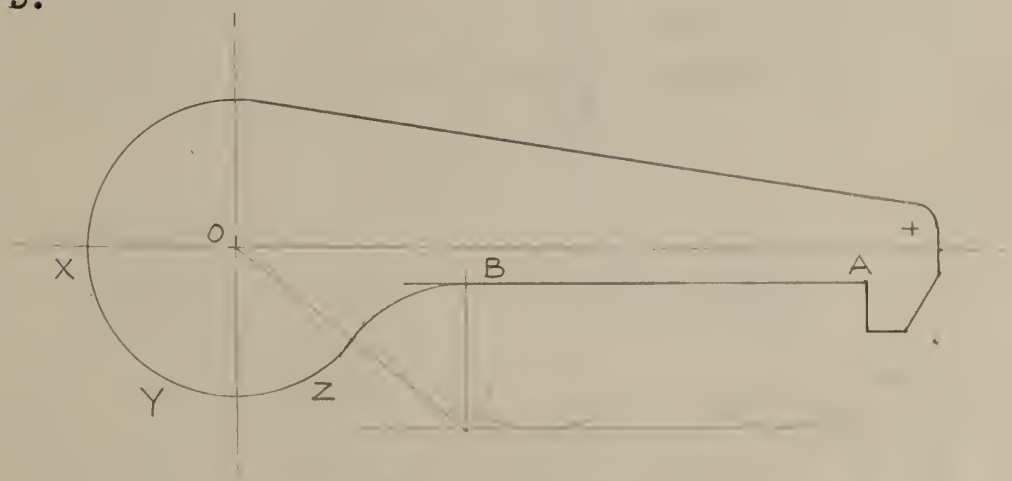
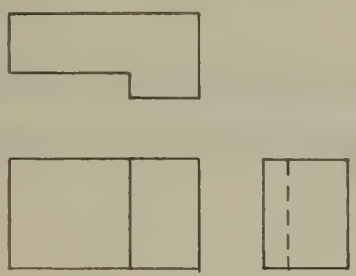


KEY

PART V

1.



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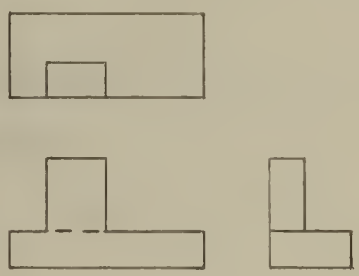
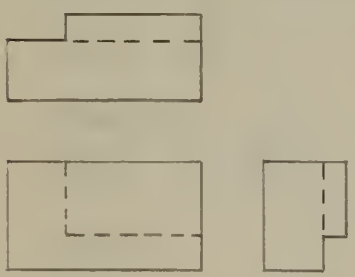


3.



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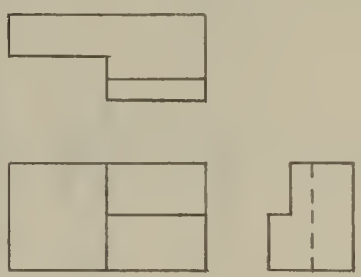

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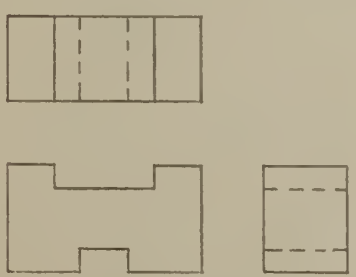

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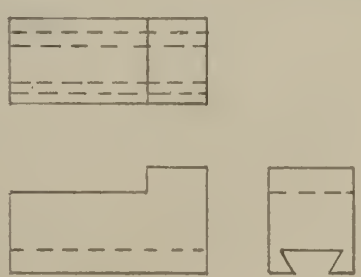

Identification Record

Name.....
Last First Middle

Age.....Date of Birth.....

High School.....

City.....State.....

Length of Drawing Period in Minutes.....

Number of Drawing Periods Per Week.....

.....

Individual Pupil Score Sheet

PART	I	Number right			=
PART	II	"	"		=
PART	III	"	"	= x 3	=
PART	IV	A "	"	= x 2	=
		B "	"	= x 2	=
PART	V	"	"	= x 3	=
PART	VI	A "	"	= x 2	=
		B "	"	= x 2	=
		C "	"	= x 2	=

TOTAL SCORE =

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(A very good test)

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(An excellent reference book; often referred to as the draftsman's Bible.)

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(Use of instruments - Good. Dimensioning. Alphabet of lines).

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(Treatment of Geometric Problems and Orthographic Projection - Excellent. Treatment of Dimensioning - Exceptional).

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(Orthographic Projection).

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(Orthographic Projection - Very good).

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(Illustrations on instruments and use of instruments are excellent. Bits of related knowledge introduces each chapter-helps to broaden out youngsters' thinking. Material very clearly presented. Truely, a modern book.)

Kellog, D. E. and DeVette, W. A., "How Well Do You Know Your Triangles", Industrial Arts and Vocational Education Magazine, (May 1933), Tracing Supplement No. 266.

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(Drawings of football field and basketball court - good for arousing student interest. Written as a series of lessons in instruction sheet form) (Some parts are a little too brief.)

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